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M-D M 8000.001

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APOLLO SYSTEM SPECIFICATION (U)

Date Effective:

May 2, 1963

GROUP-4

[redacted]

Office of Manned Space Flight
National Aeronautics & Space Administration
Washington, D.C.

~~This document contains information affecting the national defense of the United States within the meaning of the Espionage Laws, Title 18 U.S.C., Sections 793 and 794. The transmission or the the revelation of its contents in any manner to an unauthorized person is prohibited by law.~~

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OFFICE OF MANNED SPACE FLIGHT **DIRECTIVE**	**M-D** M 8000 .001 (Project)	DATE May 2, 1963

To: Distribution

From: Director of Manned Space Flight

Subject: Apollo System Specification

The enclosed document contains the approved Apollo System Specification. It shall be considered the first level technical specification for the Apollo System and the requirements set forth therein shall be fully reflected in subsidiary Apollo specifications and implemented by all cognizant elements of the Manned Space Flight Program.

The document will be updated as required by means of the change procedure described therein and reviewed quarterly to determine if the number of changes is such as to warrant a reissue. The present issue of the Apollo System Specification is about 50 percent complete. Two subsequent quarterly reissues will essentially complete the document.

In some instances this document goes into detailed specifications, which are thought necessary until the responsible Center presents a subsidiary level specification that adequately covers and controls the item in question. At that time the OMSF will review the particular item and consider its elimination from this document.

D. Brainerd Holmes 5-2-63

D. Brainerd Holmes

Enclosure

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1.0 INTRODUCTION

1.1 The purpose of this specification is:

1.1.1 To define the objectives for the development of the Apollo System and its major subsystems,

1.1.2 To define the technical approach that shall be used to implement these objectives,

1.1.3 To establish system and critical subsystem performance requirements and parameters which insure that the Apollo System meets its objectives,

1.1.4 To establish a uniform set of system design data.

1.2 The Apollo System consists of the Apollo Space Vehicle, the flight crew, the earth-based support systems and the ground crews to be employed in manned lunar exploration missions. The Apollo Space Vehicle consists of a Saturn V Launch Vehicle and the Apollo Spacecraft. The Saturn V Launch Vehicle consists of an S-IC first stage, an S-II second stage, an S-IVB third stage and an Instrument Unit. The Spacecraft consists of a Command Module (CM), a Service Module (SM), a Lunar Excursion Module (LEM), a Launch Escape System (LES), and an Adapter.

The Apollo System depends also on the development of the Saturn I and Saturn IB vehicles, which are not explicitly covered in the present issue of this document.

1.3 The requirements set forth in this Apollo System Specification shall be fully reflected in subsidiary Apollo specifications, in related contractor work statements and in the implementation of the program.

1.4 Changes in the Apollo System Specification shall be made in accordance with the procedure given in the chart on 1-3.

1.5 *Certain requirements in this specification have been identified as design objectives to reflect a degree of uncertainty on the practicability (in terms of mission reliability, scheduling, cost, etc.) of the requirement. Such design* *objectives must be pursued by the initiation and conduct of studies which are to be accomplished in sufficient time to allow incorporation of the feature(s) in the system design, if proven practicable. If study results should show a design objective requirement to be impracticable, the requirement will be appropriately modified or deleted.*

1.6 In some cases the values of quantities to be controlled by this specification have not been determined and are, therefore, left blank. Where approximate values of such quantities are known and provide useful guides for development, these are shown enclosed in brackets [ ]. Brackets are used also to identify other system characteristics which are regarded as tentative at this time. Where a change in a bracketed characteristic is deemed appropriate, notification of the change shall be sent to the appropriate directorate in MD (P) and to MD (S). MD (P) shall transmit a notice of the change to the authorized representative at each Center. No approval is required for such a change.

Firm specifications resulting from further studies of these matters will be given in future issues of this document. Prior to inclusion as firm specifications, these items shall be approved in accordance with the procedure established in Section 1.4

1) Requests for changes shall be channeled through an authorized representative at each Center. This representative shall submit requests for changes to the appropriate directorate in MD(P) and simultaneously transmit a copy to MD(S). Requests shall be transmitted to OMSF by TWX and/or letter with such supporting information as may be appropriate. Changes initiated by OMSF shall begin at step 2a.

2a) If MD(S) and MD(P) concur in the requested change, or if there is no specific non-concurrence, MD(P) shall, within 8 working days of receipt of the request in step 1, transmit by TWX to the authorized representative at each Center a notice of the proposed change to become effective 10 working days after transmittal of the notice of the proposed change.

3 aa) If no objections to the proposed change is transmitted to MD(S) and MD(P) within 8 working days after transmittal of the notice in step 2a), the requested change shall become final and MD(S) shall prepare and distribute final change sheets to holders of the system specification.

3 ab) If any center shall find the proposed change detrimental, they shall transmit such advice by TWX simultaneously to MD(S) and MD(P) within 8 working days after transmittal of the notice in step 2a). Within 2 working days of receipt of such objections, MD(P) shall rescind the notice transmitted in step 2a) and shall arrange further discussion to occur as soon as practicable among MD(S), MD(P), the originator of the change request, and the objecting parties.

4 aba) If the discussion results in agreement on the change as originally proposed, the change shall become final and MD(S) shall prepare and distribute final change sheets to holders of the system specification.

4 abb) If the discussion results in a modification of the proposed change, step 2a) and those following shall be repeated.

4 abc) If the discussion results in withdrawal of the change request, no further action is required.

4 abd) If agreement is not reached as a result of this further discussion, the decision of MD(S) and MD(P) shall stand. Further action by the originator shall proceed through normal management channels.

2b) If MD(S) and MD(P) do not concur in the requested change, MD(P) shall, within 8 working days of receipt of the request in step 1, transmit by TWX to the originator of the request a notice of their lack of concurrence, and shall invite immediate further discussion.

3 ba) If no request for further consideration is received from the originator, the request for change shall be considered to be withdrawn.

3 bb) If a request for a further consideration is received, a discussion among MD(S), MD(P), the originator of the request and other interested parties, shall be held as soon as practicable.

4 bba) If the discussion results in agreement on the proposed change, or a modification thereof, step 2a) and those following shall be taken.

4 bbb) If the discussion results in a withdrawal of the change request, no further action is required.

4 bbc) If agreement is not reached as a result of this further discussion, the decision of MD(S) and MD(P) shall stand. Further action by the originator shall proceed through normal management channels.

2.0 GENERAL APOLLO SYSTEM REQUIREMENTS.

2.1 Program Policy.

2.1.1 The objective of the Manned Lunar Exploration Program is to carry out a series of manned expeditions to the moon for the purposes of conducting exploration of the lunar surface. It is intended that the information and technology developed by the Apollo Project shall provide the foundation for a broader base of lunar activities.

2.1.2 It is program policy that no manned vehicle shall attempt landing on the lunar surface until certain information essential to system design confirmation has been obtained by measurement of the in-flight environment and the lunar surface environment at the proposed landing site. Such information may be obtained from the unmanned programs, by means of television observations, surface tests, and meteoroid and radiation experiments, or from early Apollo flight tests conducted prior to the first manned landing.

2.1.3 In the design and implementation of the Apollo System, there are many competing characteristics which must be traded off in arriving at the final configuration. Of these, there are three major competing characteristics, which are listed below in order of decreasing priority.

Crew Safety and Mission Success. Crew safety and mission success shall be the primary considerations in the design of the system. Crew safety is defined as the safe return of all three crew members whether or not the mission is completed. Mission success is defined as the safe return of all three astronauts from a completed lunar landing mission. Reliability and testing requirements, pre-launch and in-flight checkout requirements, attention to alternate and abort modes of operation and other system factors shall be developed in such a way as to achieve mission success with the least risk of life.

Schedule. Accomplishment of manned lunar landing missions at the earliest possible date is a recognized national objective. Design decisions and approaches shall be made in recognition of this exceedingly important objective, but not at the expense of confidence in crew safety and mission success.

Growth Potential. The Apollo Project is but the first step in the broad program of manned lunar exploration. To the extent that growth requirements can be anticipated and defined, accommodations will be made in the design of Apollo equipment toward meeting future requirements, so long as these do not significantly compromise crew safety, mission success and schedule.

Accomplishment of the above objectives is bounded by the fraction of total national resources allocated to the program and the rate at which such resources can be brought to bear. If and whenever cost limitations dictate program compromises, it is program policy that trade-offs of the above objectives shall be made in the stated order of priority. The application of these competing characteristics and the relative weightings given to each in the solution of any specific problem (without changing the order of priority) are matters of trade-offs and judgment. No inflexible yardstick of weightings can substitute.

2.2 System Design Policy.

2.2.1 The primary criterion governing the design of the system, including the choice of flight components, the nature and extent of pre-flight and in-flight checkout provisions, the use of ground-based computing, tracking and command capabilities, and the nature and degree of crew participation shall be that of achieving mission success with the least risk of life.

2.2.2 Where the nature of any element of the system is such that its reliability cannot be assessed with the proper confidence, then the design of the system shall be such that a failure of the element, as a goal, shall not cause loss of any crew member.

2.2.3 Although good design, adequate testing and a demonstration of reliability must be the primary means for achieving crew safety and mission success, there may be certain critical areas in the system where reliability demonstration is impractical in terms of cost and/or schedule. Every effort shall be made to minimize this uncertainty, but where it cannot be removed, the system shall be designed to include backup or alternate modes of operation wherever possible, rather than place sole reliance on simple parallel redundancy of elements whose reliability cannot be demonstrated. The net result shall be, as a goal, to preclude any single component failure from necessitating abort or seriously degrading the probability of successful abort in the event of a second component failure in the same area.

2.2.4 If the preceding reliability provisions cannot be met, then in-flight maintenance and/or parts replacement shall be provided, where practicable.

2.2.5 In those areas where requirements (performance, reliability, etc.) can be met by the existing state-of-the-art, the design of the system shall not be made dependent on the development of new components or techniques. Where a new development is required to accomplish design of the system, and is considered to involve high risk, the development shall be identified by the Centers to OMSF together with a statement of steps being taken to insure a suitable back-up capability in the event the new development effort is unsuccessful.

2.2.6 The design of all flight equipment shall be such as to accommodate the various flight tests and vehicle configurations which are planned with minimum variation of the equipment from flight test to flight test and flight test to lunar mission.

2.2.7 In the furtherance of the Manned Lunar Exploration Program beyond the initial Apollo missions, it is intended to use separately-landed support on the lunar surface to extend stay time and to expand the range and scope of lunar explorations. For example, if the nature of the separately-landed support is defined during the time in which the early design of the LEM is being accomplished, then the design of the LEM shall be such that it is compatible with the separately-landed support.

2.2.8 Removal of the landing site selenographic restrictions and stay-time and day-night limitations of the early Apollo missions is a primary objective for follow-on missions of the Manned Lunar Exploration Program.

2.3 Mission Command and Control.

(To be included in a later issue.)

3.0 APOLLO MISSION SPECIFICATION.

3.1 Mission Objectives.

The objective of initial Apollo missions shall be to land two astronauts and a minimum of 215 pounds of scientific equipment on the surface of the moon for the purpose of manned exploration of lunar surface to distances of approximately 1/2 mile from the landing site. The astronauts and a minimum of 80 pounds of scientific payload (equipment and specimens) shall be returned to Earth and safely recovered from land and water impacts.

On initial missions, the lunar landings shall be restricted to pre-selected sites on the near-earth side of the moon lying within a limited latitude band extending above and below the lunar equator. The systems shall be capable of providing a minimum stay time of____hours on the lunar surface. For these early missions, no one spacecraft shall be required to accommodate the environmental extremes of both lunar day and lunar night operations. The extra-vehicular life support shall allow crew members 4-hour periods of continuous separation from the Lunar Excursion Module (LEM). A total of at least _____man hours of extra-vehicular operation on the lunar surface shall be possible per mission.

3.2 Nominal Mission Profile.

The Apollo Mission shall be achieved by the Lunar-Orbit Rendezvous (LOR) mode. In this mode, the spacecraft, which includes a Command Module (CM), a Service Module (SM), and a Lunar Excursion Module (LEM), shall be launched from the Merritt Island Launch Area (MILA) through an earth parking orbit, into a lunar transfer trajectory by the Saturn V launch vehicle. The SM shall provide the propulsion from this point to a lunar parking orbit. Two of the three crew members in the CM shall transfer to the LEM, which shall separate from the CM/SM and descend to the lunar surface. The third crew member shall remain in the CM orbiting around the moon. After lunar exploration, the two crew members shall ascend in the LEM on a trajectory that shall permit rendezvous with the orbiting CM/SM. After the LEM crew has transferred to the CM, the LEM shall be jettisoned either in lunar orbit or during the earth transfer phase. The CM/SM shall be returned to the vicinity of the earth by SM propulsion. The SM shall be jettisoned prior to re-entry of the CM into the earth's atmosphere. The CM shall be slowed for a safe landing on water or land by aerodynamic braking and, during the final phases of the landing sequence, by parachute deployment.

The sequence of major events for the Apollo Mission shall be as indicated in the tabulation below. The major phases of the mission are in the proper sequence. The sequence of the events under each of these phases is not necessarily restricted to the order shown.

Prelaunch

1. Checkout of space vehicle to bring it to, and keep it at, an acceptable operational level.
2. Arming, Manning and Fueling.
3. Bring supporting systems to operational level.
4. Countdown.

Launch

5. Ignition of S-IC.
6. Release of holddown.
7. S-IC powered flight with gravity turn.
8. Propellant level sensor cutoff of S-IC.
9. Retro S-IC and coast for first separation.
10. Ignition of S-II.
11. Jettison interstage adapter.
12. Jettison Launch Escape System.
13. S-II powered flight controlled by Launch Vehicle Guidance.
14. Propellant level sensor cutoff of S-II.
15. Retro S-II and coast for separation.
16. Ignition of S-IVB

17. S-IVB powered flight controlled by Launch Vehicle Guidance.
18. S-IVB engine cutoff by Launch Vehicle Guidance.
19. Begin attitude control of space vehicle using S-IVB reaction control system under crew control.

Earth Parking Orbit (nominally circular, altitude of [100] nautical miles)

20. Confirm orbit by IMCC.
21. Calculation of initial conditions required to achieve the lunar transfer trajectory by onboard Guidance computer and the earth-based support system.
22. Checkout of crew and equipment.
23. Generation of command by IMCC to continue the mission.
24. Assume attitude for injection.

Injection into Lunar Transfer Trajectory

25. Ignition of S-IVB.
26. S-IVB powered flight controlled by Launch Vehicle or CM Guidance.
27. S-IVB engine cutoff by Launch Vehicle or CM Guidance.

Lunar Transfer Trajectory

28. Confirm trajectory by IMCC.
29. Checkout crew and equipment.
30. Jettison Adapter, separation and reorientation of CM/SM.
31. Docking of CM/SM with LEM.
32. Checkout of rearranged vehicle.
33. Separate CM/SM/LEM from S-IVB and Instrument Unit.
34. Begin attitude control of spacecraft by SM.
35. Optical navigational measurements.
36. Calculation of midcourse correction by CM Guidance computer and the earth-based support system.
37. Assume attitude for midcourse correction.
38. Ignition of SM.
39. SM engine cutoff by CM guidance.
40. Repeat items 35 through 39, inclusive – as required.
41. Calculation of initial conditions for entering lunar parking orbit by CM Guidance computer and the earth-based support system.

42. Generation of command by IMCC to continue the mission.
43. Assume attitude for insertion.

Insertion into Lunar Parking Orbit

44. Ignition of SM.
45. SM powered flight controlled by CM guidance.
46. SM engine cutoff by CM guidance.

Lunar Parking Orbit (nominally circular, attitude of [80] nautical miles)

47. Optical navigational measurements.
48. Calculation of lunar parking orbit parameters by CM Guidance computer and the earth-based support system.
49. Checkout of crew and equipment including LEM.
50. Transfer two crew members and equipment to LEM.
51. Continue checkout of LEM.
52. Calculation of initial conditions for descent maneuver by LEM Guidance computer and the earth-based support system.
53. Separate LEM.
54. LEM assumes attitude for descent.

LEM Lunar Descent

55. Ignition of LEM landing stage engine.
56. LEM powered flight controlled by LEM Guidance computer.

Hover, Translation and Landing

57. Hover over landing site for inspection.
58. Translation and descent maneuvers.
59. Land on lunar surface.

Lunar Surface Operations

60. Checkout of crew and equipment.
61. Exploration of lunar surface.
62. Scientific experiments and sample gathering.
63. Transmission of information back to earth.
64. Checkout of LEM, assisted by earth-based support system, to bring it to, and keep it at, an acceptable operational level.
65. Obtain orbital parameters of CM/SM.

66. Calculation of initial conditions for ascent maneuver by LEM Guidance computer and the earth-based support system.

Lunar Launch

67. Ignition of LEM launch engine and separation from lunar landing stage.
68. LEM powered flight controlled by LEM Guidance.
69. Midcourse corrections, as required.

Rendezvous in Lunar Orbit

70. LEM rendezvous with CM/SM.
71. Dock LEM to CM/SM.
72. Transfer of LEM crew and scientific material to the CM/SM.
73. Jettison LEM.*
74. Checkout of crew and equipment.
75. Calculate initial conditions for injection into Earth transfer trajectory by CM Guidance computer and the earth-based support system.
76. Assume attitude for injection.

Injection into Earth Transfer Trajectory

77. Ignition of SM engine.
78. SM powered flight controlled by CM Guidance.
79. SM engine cutoff by CM Guidance.

Earth Transfer Trajectory

80. Confirm trajectory by IMCC.
81. Checkout of CM/SM aided by the earth-based support system.
82. Optical navigational measurements.
83. Calculation of initial conditions for midcourse correction by CM Guidance computer and the earth-based support system.
84. Assume attitude for midcourse correction.
85. Ignition of SM.

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*If SM propellant reserves permit, the LEM may be jettisoned during the earth transfer phase.

86. SM engine cutoff by CM Guidance.
87. Repeat items 82 through 86 inclusive as required.
88. Calculate required guidance parameters for achieving landing site.
89. Jettison SM.
90. Assume re-entry attitude.

Re-entry

91. Maneuver to vicinity of a landing site.
92. Deploy parachutes.
93. Start recovery equipment.
94. Deploy landing aids.
95. Land on earth.

Recovery

96. Recovery.

3.3 Reference Trajectories.

(To be included in a later edition.)

3.4 Mission Abort Options.

(To be included in a later edition.)

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4.0 SUBSYSTEM SPECIFICATIONS

4.0 SUBSYSTEM SPECIFICATIONS

4.1 Apollo Space Vehicle.

4.1.1 General.

The primary mission mode shall be Lunar-Orbit Rendezvous. The Apollo space vehicle at launch shall consist of a Saturn V launch vehicle and an Apollo spacecraft as described below. The control weights and tanks capacities of the stages and modules shall be in accordance with the Apollo Control and Design Goal Weights document.

a) Saturn V Launch Vehicle. This vehicle consists of an S-IC stage, an S-II stage, an S-IVB stage, and an Instrument Unit. It shall be 33 feet nominal outside diameter, excluding protrusions and 280 to 283 feet in length. The nominal total weight of the launch vehicle and the spacecraft shall be 6,000,000 pounds at lift-off.

b) Apollo Spacecraft. The spacecraft shall consist of a Command Module (CM), a Service Module (SM), a Lunar Excursion Module (LEM), an Adapter and a Launch Escape System (LES). It shall be 13 feet nominal outside diameter excluding the Adapter, and 52 to 54 feet in length (not including its Launch Escape System).

4.1.2 Structural Design Requirements.

The space vehicle structure shall be designed to meet the applicable environmental requirements given in section 4.1.3. The space vehicle structure shall be designed to resist all loads and combination of loads that may be expected to occur during all phases of testing, transportation, erection, checkout, launch and flight with adequate margins of safety. These load requirements shall include but not be limited to the following conditions:

4.1.2.1 Prelaunch Loads. The Apollo space vehicle shall have a free standing capability on the launch pad during all winds of the strongest wind month as given by the 99.9 percent probability-of-occurrence table in OMSF Program Directive M-DE 8020.008A.*

4.1.2.2 Ignition Loads. The vehicle shall be designed to resist the dynamic loads resulting from engine start transients, vehicle release after normal hold down and engine cutoff transients during the hold down period.

4.1.2.3 Launch Loads. The vehicle shall be structurally capable of being launched in the highest wind speeds that may occur during the strongest wind month as given by the 99% probability of occurrence table. The vehicle shall be capable of flight during the launch phase in the quasi steady-state wind speeds plus the associated wind shears and wind speed changes that may occur 95% of the time during the strongest wind month. The reference design wind speeds shall be as specified in OMSF Program Directive M-DE 8020.008A.* The structure shall be capable of withstanding a thrust acceleration of 5g axial and a disturbed $q\alpha$ of 35,000 Kg degrees/meters^2 during launch vehicle flight.

4.1.3 Environmental Requirements.

4.1.3.1 Natural Environments. The design shall be capable of withstanding the natural environments that might reasonably be expected to occur.

As a design objective, the space vehicle shall be designed so that there is a 99.9% probability of not having meteoroid penetration result in having to abort the mission.

The reference conditions for natural environment shall be as given in OMSF Program Directive M-DE 8020.008A.*

4.1.3.2 Induced Environments. The vehicle shall be designed so that all components and subsystems shall operate properly when exposed to the vibration, shock, noise, temperature, pressure and radio frequency environments resulting during the normal operation of the vehicle and its subsystems while performing its mission.

*OMSF Program Directive M-DE 8020.008A - Natural Environment and Physical Standards for Project Apollo. Issue date August 1963.

4.1.4 Stability and Control Requirements.

4.1.4.1 For design purposes the minimum lift-off thrust to weight ratio for the complete vehicle including payload shall be 1.25.

4.1.4.2 The maximum dynamic angle of attack shall be 9.6 degrees at maximum q α.

4.1.5 Launch Interface Requirements.

4.1.5.1 Provisions shall be made to allow remote checkout, testing and conditioning by the checkout computers at MILA.

4.1.5.2 The vehicle shall be capable of being loaded with propellants, conditioned and checked out in __hours on the launch pad. The vehicle shall be capable of being launched in __hours after a delay that requires draining on the launch pad.

4.1.5.3 The vehicle shall be capable in the loaded condition of __hours standby time. This includes propellant topping on the pad before launch.

4.1.5.4 The space vehicle shall weigh no more than 600,000 pounds when unloaded for transporting on the crawler-transporter.

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4.2 Launch Vehicle.

4.2.1 General.

4.2.1.1 Configuration. To perform the primary mission as stated in section 3.2, the Saturn V Launch Vehicle shall consist of three stages and an Instrument Unit as described below.

a) First Stage (S-IC). The S-IC Stage shall be 33 feet nominal diameter, 137 to 139 feet in length and powered by five F-1 engines with a total sea level thrust of 7,500,000 pounds. Propellants shall be liquid oxygen and RP-1.

b) Second Stage (S-II). The S-II Stage including the interstage shall be 33 feet nominal diameter, 80 to 82 feet in length and powered by five J-2 engines with a total nominal vacuum thrust of 1,000,000 pounds. Propellants shall be liquid oxygen and liquid hydrogen.

c) Third Stage (S-IVB). The S-IVB Stage including the interstage shall be 22 feet nominal diameter, 58 to 60 feet in length and powered by one J-2 engine with a total nominal vacuum thrust of 200,000 pounds. Propellants shall be liquid oxygen and liquid hydrogen.

d) Instrument Unit. The Instrument Unit shall be cylindrical in shape with a nominal diameter of 22 feet and a length of three feet. This unit shall contain equipment associated with the overall launch guidance, control, and instrumentation such as the stabilized platform, guidance and control computers, instrumentation and measuring equipment, switch selector, command receiver and decoder, antennas, power supplies, and in-flight environmental conditioning.

4.2.1.2 Operational Modes. The normal operational mode shall be suborbital start of the S-IVB, followed by coast in earth parking orbit, and then restart of the S-IVB to provide the velocity required for injection into lunar transfer trajectory. *As design objectives the launch vehicle shall be capable of achieving the required lunar transfer trajectory using any one of the following conditions:*

a) Orbital start of the S-IVB with the first two stages carrying an off-loaded S-IVB with its payload to earth orbit.

b) One engine out in the S-IC after time of maximum q.

c) One engine out in the S-II from the time of ignition.

4.2.1.3 Payload Capability. The Saturn V Launch Vehicle shall be capable of boosting the following net payloads at injection into the [72 hour] lunar transfer trajectory. Net payload consists of all weight at the time of injection forward of the Instrument Unit. The payloads are based on launching from the Merritt Island Launch Area with a thrust-to-weight ratio at lift-off of 1.25, an azimuth of $90^\circ \pm 18^\circ$, jettisoning the 6600-pound LES 10 seconds after ignition of the second stage, parking 4 1/2 hours in earth orbit, operating 2 hours after injection before separation of the SIV-B, and providing an orbital injection window time of 2 minutes.

a) 90,000 pounds using the normal operational mode.

b) 82,500 pounds using the design objectives of either orbital start of the S-IVB or engine out operation of the S-II stage from the time of ignition.

As a design objective these payload capabilities shall be increased to:

c) 97,500 pounds for the normal operational mode.

d) 90,000 pounds for the design objectives of either orbital start of the S-IVB or engine out operation of the S-II stage from the time of ignition.

4.2.2 Structural Design Requirements.

The structural design requirements on the launch vehicle shall be as described in section 4.1.

4.2.3 Propulsion and Reaction System.

4.2.3.1 S-IC Stage.

4.2.3.1.1 The S-IC Stage propulsion shall provide a nominal sea level thrust of 7,500,000 pounds and a minimum sea level value of specific impulse of 260 seconds. This thrust shall be provided by five F-1 engines. Four of these engines shall be equally spaced on a circle and shall be gimballed for thrust vector control. The fifth engine shall be mounted on the centerline of the stage and shall be non-gimballed. Automatic emergency engine cutoff shall be provided for all engines. Normal engine shutdown shall be initiated by propellant level sensors.

Propellants for this stage shall be RP-1 and liquid oxygen. The propellant loading for this stage shall be based on an optimization which assumes five engine operation; *however, as a design objective, the stage shall be capable of controlled operation with one engine out after time of maximum q.*

4.2.3.1.2 Solid propellant retrorockets shall be provided for stage separation.

4.2.3.1.3 Unused propellants resulting from mixture ratio shift shall be kept below 30,000 pounds.

4.2.3.2 S-II Stage.

4.2.3.2.1 The S-II Stage propulsion shall provide a nominal vacuum thrust of 1,000,000 pounds and a minimum vacuum specific impulse of 424 seconds. The thrust shall be provided by five J-2 engines. Four of these engines shall be equally spaced on a circle and shall be gimballed for thrust vector control. The fifth engine shall be mounted on the centerline of the stage and shall be non-gimballed. Automatic emergency engine cutoff shall be provided for all engines. Normal engine shutdown shall be initiated by propellant level sensors or from the vehicle guidance system.

Propellants for this stage shall be liquid hydrogen and liquid oxygen. The propellant loading for the stage shall be based on an optimization which assumes five engine operation; *however, as a design objective the stage shall be capable of controlled operation with one engine out.*

4.2.3.2.2 Solid propellant retrorockets shall be provided for stage separation.

4.2.3.2.3 Solid propellant ullage rockets shall be provided for propellant setting prior to stage ignition.

4.2.3.2.4 A propellant utilization system shall be provided which shall maintain the mixture ratio between 4 and 6. Unused propellants resulting from mixture ratio shift shall not exceed _____ pounds.

4.2.3.3 S-IVB Stage.

4.2.3.3.1 The S-IVB Stage propulsion shall provide a nominal vacuum thrust of 200,000 pounds and a minimum vacuum specific impulse of 422 seconds. The thrust shall be provided by one J-2 engine which shall be located on the stage centerline and shall be gimballed. Automatic emergency cutoff shall be provided. Normal engine shutdown shall be initiated from the vehicle guidance system. The system shall be capable of one restart. Propellants for this stage shall be liquid hydrogen and liquid oxygen. Boil-off shall be less than [4000] pounds of propellant during 4 1/2 hour coast in earth parking orbit.

4.2.3.3.2 An auxiliary propulsion system shall be included in the S-IVB stage. This system shall provide:

a) Roll stabilization from time of first ignition of the S-IVB stage until separation of the S-IVB stage from the spacecraft.

b) Acceleration for propellant settling prior to main engine ignition.

c) Attitude control during coast.

d) Acceleration for propellant settling for ullage venting during coast.

This system shall be capable of stabilizing the space vehicle for 4 1/2 hours during earth parking orbit plus 2 hours after the time of injection into lunar transfer trajectory. It shall also be capable of performing the required altitude maneuvers for navigational sightings during the earth orbital phase.

4.2.3.3.3 Means shall be provided by using existing hardware and residual fuels to alter the flight path of the S-IVB from that of the spacecraft after separation from the spacecraft.

4.2.3.3.4 *As a design objective, a third burn of the S-IVB shall be used after separation from the spacecraft to obtain escape velocity to prevent reentry into the earth's atmosphere.* If this design objective is achieved, the requirement of 4.2.3.3.3 may be modified.

4.2.3.3.5 A propellant utilization system shall be provided which shall maintain the engine mixture ratio between 4 and 6. Unused propellants resulting from mixture ratio shift shall not exceed [1000] pounds.

4.2.4 Stage Separation.

The short coast mode shall be used to separate all stages of the Saturn V Launch Vehicle. Stages shall be capable of successful separation in the event of failure of one retro motor. Failure of one ullage motor shall not prevent effective propellant positioning and vehicle control.

4.2.5 Guidance and Control System.

The guidance and control system of the Launch Vehicle shall meet the requirements given in section 4.4.

4.2.6 Tracking Subsystem.

The Launch Vehicle shall contain transponders for use with the ground tracking stations. Requirements for these equipments are presented in section 4.5.

4.2.7 Telemetry.

Each stage of the Launch Vehicle and the Instrument Unit shall contain a telemetry system. Requirements for these systems are presented in section 4.5.

4.2.8 Ground-to-Space Data Subsystem.

The receiving equipment for the Ground-to-Space Data System shall be located in the Instrument Unit. Requirements for this equipment are presented in section 4.5.

4.2.9 Emergency Detection Subsystem.

To be included in a later edition.

4.2.10 Command Destruct Subsystem.

The Launch Vehicle shall contain two separate systems for emergency flight termination on each stage. These systems shall be compatible with the AMR Range Safety Code. Requirements for these systems are presented in section 4.5.

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4.3 Spacecraft.

The spacecraft subsystem specifications are presented in two groups in this section. Section 4.3.1 presents overall requirements for the spacecraft and the individual modules. Section 4.3.2 through 4.3.10 cover the requirements imposed on individual spacecraft systems. The system design policy for the spacecraft shall be in accordance with section 2.2.

4.3.1 Functional Requirements.

To perform the primary mission as stated in section 3.2, the Apollo Spacecraft shall consist of a Command Module (CM), a Service Module (SM), a Lunar Excursion Module (LEM), a Launch Escape System (LES), and an Adapter. The spacecraft shall weigh no more than 96,600 pounds at lift-off and no more than 90,000 pounds at injection into lunar transfer trajectory. These weights include provision for a minimum margin of 10 percent over the minimum velocity increments indicated in the Velocity Increment Budget in Appendix A-3. *As a design objective, it shall be capable of being offloaded to 82,500 pounds at injection and provide a margin of 10 percent over the minimum velocity increments indicated in Appendix A-3.*

The CM, LEM and spacesuits and their equipments shall be designed to minimize the fire hazard inherent in the use of a pure oxygen atmosphere.

4.3.1.1 Command Module. The Command Module shall be the spacecraft command center where crew-initiated control functions shall be performed. It shall contain a pressurized cabin to accommodate three astronauts and the systems necessary for crew support, guidance, navigation, contron, and recovery of the spacecraft. Those components and systems not required by the CM after the CM separates from the SM for re-entry into the earth's atmosphere may be physically located in the SM. The CM systems shall allow the CM to perform the functions stated below.

4.3.1.1.1 The CM shall be used for controlled re-entry into the earth's atmosphere and be capable of surviving either a land or water landing.

4.3.1.1.2 The CSM shall be used for docking with the LEM and allow the transfer of two crew members to the LEM within the controlled environment of the spacecraft.

4.3.1.1.3 The CM shall allow a crew member to exit into space or to enter the CM from space without assistance from any other crew member when the CM is not docked to the LEM. It shall be possible for the LEM crew to effect an entry into the CM without benefit of hard dock (in the event of difficulty with docking but providing the modules are stable) or the active participation of the crew member in the CM.

4.3.1.1.4 The CM shall be designed such that a single crew member can return the CM safely to earth from any point in the mission profile.

4.3.1.1.5 The CM shall be designed such that a single crew member while in lunar orbit can perform all essential CM operations for at least seven days.

4.3.1.1.6 The CSM and its crew member shall have the capability of rendezvous with the LEM and rescue of the LEM crew in lunar orbit. The capability shall not be limited in any way by CSM guidance and control capability; the only limitation shall be SM propulsion available for rescue.

4.3.1.2 Service Module. The Service Module shall have the capability of providing all spacecraft propulsion and reaction control needs from lunar transfer injection until SM separation prior to re-entry into the earth's atmosphere except for LEM separation, landing and return to lunar orbit. In addition, the SM shall have the capability of providing the propulsion and reaction control needs for aborts after jettison of the LES.

4.3.1.3 Lunar Excursion Module. The Lunar Excursion Module (LEM) shall be composed of two stages. The upper stage shall be the Ascent Stage and shall contain a command center where crew-initiated control functions shall be performed during the lunar landing, lunar stay and return to lunar orbit portion of the mission. It shall contain a pressurized cabin to accommodate two astronauts and the systems necessary for crew support, guidance, navigation, control, lunar descent, exploration and return to the CSM in lunar orbit. The Ascent Stage propulsion and reaction control systems shall have the capability of providing all LEM propulsion and reaction control needs for launch from the lunar surface to lunar orbit and rendezvous and dock with the CSM. The reaction control system shall also supply the reaction control needs during separation from the CM, descent for terminal landing, hover, translation and landing on the lunar surface.

The lower stage shall be the Descent Stage and shall contain the landing aids, landing gear, components and systems not required for the return to lunar orbit and rendezvous, and the landing propulsion system. This propulsion system shall have the capability of providing all LEM propulsion needs for separation from the CM, descent for terminal landing, hover, translation and landing on the lunar surface.

The systems of both stages shall allow the LEM to perform the functions stated below.

4.3.1.3.1 The LEM shall be capable of carrying to the lunar surface a minimum of 215 pounds of scientific equipment and two astronauts for lunar surface exploration and returning to the CM a minimum of 80 pounds of this equipment and/or lunar samples and the crew.

4.3.1.3.2 The LEM shall provide the necessary support for the operation and control of the scientific equipment and the processing and transmitting of scientific data. The interface with the scientific payload in terms of allowable weight, available space, electrical power requirements, thermal control requirements, impedance levels, etc., shall remain essentially invariant from mission to mission and payload to payload for initial missions.

4.3.1.3.3 The LEM shall be capable of operation for at least 48 hours while separated from the CM.

4.3.1.3.4 The LEM shall be capable of 45 hours operation on the near earth side of the lunar surface during any phase of the lunar day-night cycle. For initial missions, however, no one mission or spacecraft shall be required to accommodate the environmental extremes of both day and night operations.

4.3.1.3.5 The LEM shall be capable of performing a controlled soft landing and take-off at any point in the landing area where the lunar surface characteristics, such as slope, protuberances, bearing strength, etc., fall within range of the surface conditions specified in the lunar model for Apollo mission. This model is presented in OMSF Program Directive M-DE 8020.008A.

4.3.1.3.6 The LEM shall be the primary vehicle for effecting rendezvous and dock with the CM in lunar orbit. It shall be designed to permit docking with the CM and allow the transfer of the crew to the CM within the controlled environment of the spacecraft.

4.3.1.3.7 It shall be possible for the CM crew member to effect an entry into the LEM without benefit of a hard dock (in the event of difficulty with docking but providing the modules are stable) or the active participation of crew members in the LEM.

4.3.1.3.8 The Descent Stage shall act as the launch platform for the Ascent Stage on the lunar surface. The Descent Stage shall have the capability of being staged at any time during descent to allow the Ascent Stage to return the crew to the CSM in orbit.

4.3.1.3.9 The LEM shall allow a single crew member to perform all essential functions associated with lunar landing, take-off, rendezvous and dock.

4.3.1.3.10 The LEM shall allow unassisted crew exit into and entry from space, both when docked to the CM and when the LEM is separated, and to lunar surface when landed. The LEM shall be designed to permit one crewman to effect an unassisted rescue of another on the lunar surface.

4.3.1.4 Launch Escape System. The Launch Escape System (LES) shall provide abort propulsion requirements for the CM from the time the Apollo Space Vehicle is on the launch pad until ___ seconds after second stage ignition. It shall be capable of separating the CM from the space vehicle to a safe distance in a time consistent with surviving a launch vehicle explosion without exceeding the acceleration limits that can safely be applied to the astronauts.

4.3.1.5 Adapter. The Adapter shall be the structural element connecting the spacecraft to the launch vehicle during launch and injection into the translunar trajectory. It shall permit access to the LEM for pre-launch check-out and conditioning.

4.3.2 Structure.

The individual modules, LES, Adapter and the complete spacecraft shall be designed to meet all requirements of section 4.1.2. The required strength shall not be dependent on pressurization of the propellant tanks. Control of heat transferred to the propellant tanks shall be accomplished without the use of active control systems.*

The available volume for unrestricted crew movement within the crew cabins shall produce no significant loss in the functional capability of the crew.

Minimum interior dimensions shall allow the crew members to move about while wearing inflated pressure suits.

4.3.2.1 Command Module. The CM shall have a nominal diameter of 13 feet, excluding protrusions, and a length of 13 feet. The structure shall provide a protected pressurized vessel to house 3 astronauts and equipment. It shall carry the required heat shield, provide the aerodynamic shape required for re-entry, and meet the following requirements with sufficient margins of safety.

4.3.2.1.1 The structure shall be designed for the impact decelerations of landing, and shall keep the forces transmitted to the astronauts within safe limits. For land landing, the surface characteristics shall be considered to be equivalent to those of a concrete runway with landing area surface winds equivalent to the 99% probability of occurrence values of OMSF Program Directive M-DE 8020.008A. For water landings, the structure shall be water tight and capable of floating for a minimum of seven days in ocean environments corresponding to sea state 6 with the surface winds of ___ knots. The CM center of gravity location shall be such as to allow the CM to float in a position for exiting the crew independent of the landing orientation.

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* Active control systems as used here include all temperature control systems with moving parts, or systems that require controlled orientation with respect to the Sun.

4.3.2.1.2 The structure shall be designed to withstand the effects of abnormal re-entry determined by the following trajectories: (1) A normal corridor undershoot re-entry at -7.7 degree flight path angle in the case where the initial pullout maneuver has been completed too early resulting in a 20g deceleration load; (2) A re-entry corridor having an earth entry-flight-path angle of -10 degrees for the under shoot boundary which results in a 20g deceleration load during the initial pullout phase.

4.3.2.1.3 The structure shall be designed to provide window area located so as to allow the rendezvous and docking to be performed by the CM using direct optical means.

4.3.2.1.4 The structure shall provide an aerodynamic configuration giving a lift-drag ratio (L/D) equal to 0.5 at a Mach number of 6 or greater.

4.3.2.1.5 The structure of the pressure vessel shall contain space to allow at least one crew member at a time to stand erect or lie flat.

4.3.2.1.6 *As a design objective the CM structure shall be capable of withstanding the thrust loads encountered in using the LEM for spacecraft abort propulsion.*

4.3.2.2 Service Module. The SM shall have a nominal diameter of 13 feet, excluding protrusions, and a length of 14 feet, excluding protrusions and the nozzle extension.

The structure shall provide for the transmission of the primary spacecraft propulsion system thrust loads and meet the space vehicle structural requirements in section 4.1.2. The SM structure shall be capable of withstanding the thrust loads encountered in using the LEM spacecraft abort propulsion.

4.3.2.3 Lunar Excursion Module. The Lunar Excursion Module, not including the landing gear legs, shall fit within an envelope described by a right truncated cone with a vertex angle of ___ degrees, a base diameter of ___ feet, and a height of ___ feet. With the legs in the stowed position, the LEM shall fit within the free volume of the adapter and instrument unit.

As a design objective, the LEM structure shall be capable of transmitting the thrust loads encountered in using the LEM for spacecraft abort propulsion in addition to meeting the normal mission structural requirements.

The LEM shall be designed to keep the forces transmitted to the astronauts within safe limits.

4.3.2.3.1 LEM Ascent Stage. The structure shall provide a pressurized vessel having a volume consistent with astronaut comfort. It shall house two astronauts and equipment; be capable of withstanding the forces resulting from the propulsion system thrust, lunar surface impact, and docking; and shall meet the following requirements:

a) The design shall allow for lunar lift-off with a tilt of the landing stage from the vertical of up to 30 degrees.

b) The structure shall be designed to provide window area located so as to allow the lunar landing, docking, and rendezvous to be observed using direct optical means.

4.3.2.3.2 LEM Descent Stage. The structure shall be capable of transmitting propulsion system thrust loads and shall provide suitable lunar landing gear for landing on the lunar surface under the following conditions:

a) Lunar surface characteristics (rocks, dust, slope, bearing strength, etc.) as described in OMSF Program Directive M-DE 8020.008A.

b) Maximum 10 feet per second vertical velocity 5 feet per second horizontal velocity with main engine thrust zero, and with maximum final vehicle orientation angel of 5° as determined by the vehicle x axis and the local vertical.

4.3.2.4 Launch Escape System. The LES shall fit within an envelope described by a right truncated cone with a vertex angle of 8 degrees, a base diameter of 6.5 feet, and a height of 34 feet. The structure shall provide for the transmission of the LES propulsion thrust loads and meet the space vehicle structural requirements in Section 4.1.2.

4.3.2.5 Spacecraft Adapter. The adapter shall have a nominal top diameter of 13 feet, a bottom diameter of 22 feet, and a length of 27 to 29 feet.

The structure shall provide for the transmission of the earth launch loads to the spacecraft and meet the space vehicle structural requirements in section 4.1.2.

4.3.3 Propulsion and Reaction Control Systems.

4.3.3.1 Command Module. The CM reaction control system shall be used only after jettison of the SM. It shall effect the attitude control required by the CM during the re-entry phase and during launch abort. The reaction control system shall have complete redundant capability. The engines shall be capable of operating in both a pulsed mode and a continuous mode. Each engine shall provide a minimum of 200 seconds reliable operating time with a minimum vacuum specific impulse of 286 seconds when operated for periods exceeding 1 second. The propellant shall be N_2O_4 and MMH, and shall be pressure-fed to the engine using a positive expulsion system with provision for propellant jettisoning.

4.3.3.2 Service Module. The SM propulsion shall supply the spacecraft velocity increments as indicated in the Velocity Increment Budget given in Appendix A-3.

4.3.3.2.1 The main propulsion system in the Service Module shall supply all required impulses in excess of 5,000 pound-seconds. This system shall consist of one pressure-fed engine that is gimbaled and located on the centerline of the vehicle. It shall be capable of at least (30) restarts in flight. This engine shall have a nominal initial thrust of 21,900 pounds. The 3σ minimum vacuum specific impulse throughout 750 seconds of operation shall be (313) seconds. The propellants shall be N_2O_4 and a fifty-fifty blend by weight of UDMH and N_2H_4 and shall be pressure-fed to the engines. A propellant utilization control system shall be provided so that unused propellants resulting from mixture ratio shift shall not exceed 0.5% of the initial propellant weight.

4.3.3.2.2 The reaction control system in the Service Module shall:

a) Supply all required impulses of_____pound-seconds or less

b) Provide acceleration for propellant setting for main engine ignition

c) Effect the attitude control of the SM/CM/LEM spacecraft configuration and the CSM spacecraft configuration

The reaction control system shall have complete redundant capability. The engines comprising this system shall be capable of operating both in a continuous and in a pulse mode. Each engine shall be capable of providing a minimum of [1,000] seconds reliable operating time with a minimum vacuum specific impulse of 300 seconds when operating for periods exceeding 1 second. The propellants for this system shall be the same as for the main propulsion system and shall be pressure-fed to the engines using a positive expulsion system. *As a design objective, propellants in the main engine tanks shall be transferable to the reaction control system.*

4.3.3.3 Lunar Excursion Module. The lunar Excursion Module propulsion system shall supply the velocity increments indicated in the Velocity Increment Budget given in Appendix A-3. The LEM shall be composed of two stages: a Descent Stage and an Ascent Stage. The propulsion systems for these stages are presented below.

4.3.3.3.1 LEM Descent Stage. There shall be one propulsion system in the LEM Descent Stage. This system shall supply propulsion for descent and landing on the lunar surface. It shall consist of one pressure-fed engine that is gimbaled and located on the centerline of the vehicle. This engine shall be capable of a 10:1 controlled variation in thrust from a nominal maximum thrust of 10,500 pounds. The 3σ minimum vacuum specific impulse at maximum thrust at end of burn shall be 305 seconds and the minimum vacuum specific impulse at minimum thrust shall be 285 seconds. This engine shall be capable of [6] restarts in flight. The propellants shall be N_2O_4 and a fifty-fifty blend by weight of UDMH and N_2H_4.

4.3.3.3.2 LEM Ascent Stage. There shall be a main propulsion system and a reaction control system in the LEM Ascent Stage.

The main propulsion system shall supply the thrust for launching from the lunar surface and for initial docking maneuvers. This system shall consist of one pressure-fed engine that is fixed and located on the centerline of the vehicle. The engine shall have a nominal initial thrust of 3,500 pounds. The 3σ minimum vacuum specific impulse at end of burn shall be 303 seconds. This engine shall be capable of ___ restarts. The propellants shall be N_2O_4 and a fifty-fifty blend by weight of UDMH and N_2H_4 and shall be pressure-fed to the engine.

The reaction control system shall:

a) Supply impulse for rendezvous and docking maneuvers.

b) Provide acceleration for propellant settling for main engine ignition of both the lunar landing and lunar launch stages.

c) Provide acceleration for propellant settling for main engine ignition of both the lunar landing and lunar launch stages.

d) Effect the attitude and thrust vector control of the ascent/descent configuration of the LEM and the ascent configuration of the LEM.

The reaction control system shall have complete redundant capability. The engines comprising this system shall be the same configuration as used for the SM reaction control system. These engines shall be capable of operating in both a continuous and pulse mode. Each engine shall be capable of providing a minimum of [1,000] seconds reliable operating time with a minimum vacuum specific impulse of 300 seconds when operating for periods exceeding 1 second. The propellants shall be the same as for the main propulsion system and shall be pressure-fed to the engines using a positive expulsion system. Propellants in the main engine tanks shall be transferable to the reaction control system.

4.3.3.4 Launch Escape System. Propulsion for the Launch Escape System (LES) shall be provided by three solid propellant motors with the following requirements:

a) The Launch Escape Motor shall be capable of separating the command module from the launch vehicle.

b) The Pitch Control Motor shall be capable of providing the pitching moment required to control the abort trajectory.

c) The Tower Jettison Motor shall be capable of separating the LES from the command module after second stage ignition during a normal mission or after the Launch Escape Motor has functioned for an aborted mission.

4.3.4 Guidance and Control System.

Two separate guidance and control systems shall be used on the spacecraft. The first shall be primarily for the guidance and control of the SM/CM/LEM and the CSM spacecraft configuration. Parts of this system shall be used for the control of CM during re-entry. This system shall be located in the CM; however, components not required for re-entry, and which need not be accessible to the crew for normal operation, may be located in the SM. The second system shall be used for the guidance and control of the LEM and shall be physically located in the LEM. The two systems shall use identical hardware wherever their requirements permit. Requirements for these systems are presented in section 4.4.

Transponders shall be located in the CM and in the LEM to permit tracking of both the CM and LEM by Earth. Systems shall also be provided for tracking the CSM by the LEM and, for tracking the LEM by the CSM. Requirements for these systems are presented in sections 4.4, 4.5, and 4.8.

4.3.5 Communication System.

Two separate systems shall be used on the spacecraft. The first shall be for two-way voice and data transmission between the CM and earth, and between the CM and the LEM. This system shall be physically located in the CM and SM. The second shall be for two-way voice and data transmission between the LEM and earth and between the LEM and the CM. Portions of this system shall also be used to relay two-way voice between the astronauts on the lunar surface to earth and to the CM. This system shall be physically located in the LEM. Requirements for these systems are presented in section 4.5.

4.3.6 Operational Instrumentation System.

(This section will be included in a later issue of the specification.)

4.3.7 Scientific Instrumentation System.

(This section will be included in a later issue of the specification.)

4.3.8 Re-Entry and Earth Landing System.

The Re-entry and Earth Landing System of the Command Module shall consist of a heat shielding system, a parachute system, and an impact attenuation system. These systems in their primary mode shall operate automatically and shall permit a controlled re-entry using atmospheric braking in an entry corridor determined primarily from crew safety considerations. The entry corridor shall be bounded by the following flight path angles as measured from the local horizontal:

a) -5.5 degrees for the overshoot boundary

b) -7.7 degrees for the undershoot boundary

The maximum deceleration during normal re-entry shall not exceed 10g.

During the re-entry, energy management and range control shall be accomplished by controlling the direction of the lift vector. The CM shall have a lift-drag ration of 0.5 at a Mach number of 6 or greater with a fixed angle of attack. Directional variation of the lift vector shall be accomplished by control of the vehicle's roll attitude with the reaction jets. The parachute system shall be deployed for terminal landing and shall be capable of reducing the velocity of the CM to less than 30 ft/sec by time of touch-down on water or land at elevations up to 5,000 feet. *As a design objective, the parachutes shall be controllable for varying the landing point on earth.*

4.3.9 Life Support Systems

The Life Support Systems shall be designed to meet the requirements listed under section 4.3.1 and the following paragraphs.

4.3.9.1 Crew Provisions and Equipment.

4.3.9.1.1 Command Module/Service Module. The CSM shall be equipped with a non-regenerative life support system, including food, adequate for |38| man-days operation.

Between SM separation and touchdown, the life support system in the CM shall maintain metabolic and environmental requirements for ___ hours without dependence on portable life support systems.

After landing on earth or water, the CM shall provide a survivable environment and necessary provisions for three men for [7] days.

4.3.9.1.1.1 Water. The fuel cell in the SM shall be the primary source of potable water for the crew. In addition, a minimum of a [1] day supply of potable water shall be provided in a removable container in the CM at launch and held in reserve for survival requirements.

Provisions shall be made to collect waste water from other sources (e.g., cabin atmosphere, etc.) and to store it separately from the water supplied by the fuel cell.

4.3.9.1.1.2 Rest Arrangements. The CM shall be designed to accommodate one crewman resting in a prone position during the flight.

4.3.9.1.2 Lunar Excursion Module. The LEM shall be equipped with non-regenerative life support system including food, adequate for a minimum of 4 man-days operation.

4.3.9.1.2.1 Water. *As a design objective, water required for consumption, cooling and other needs shall be obtained from the CM reserves prior to LEM separation.* Arrangements shall be made for storage, heating, and cooling of water.

4.3.9.1.3 Spacesuits. Each crewman shall be equipped with one full-pressure spacesuit, designed to protect the astronaut against the conditions of lunar and space environments listed in OMSF Program Directive M-DE 8020.008A and to satisfy the environmental requirements listed in section 4.3.9.2. The spacesuit shall be of anthropomorphic design and shall:

a) incorporate required biophysical sensors;

b) provide for collection of body wastes;

c) be designed for operation with the environmental control systems of the CM, LEM and back packs, and have quick connect and disconnect capabilities;

d) *as a design objective, permit the reading of displays and operation of controls with no impairment over "shirtsleeve" operation;*

e) provide sufficient mobility to permit the crewman to perform all functions essential to mission success; and

f) permit donning, without assistance, in [5] minutes

The spacesuit assembly shall incorporate communications equipment designed to meet the requirements listed in section 4.5.

4.3.9.1.4 Portable Life Support Systems (Back Packs). One back pack shall be provided for each crew member. *As a design objective one spare back pack shall be provided for the LEM crew.* Each back pack shall provide life support for extra-vehicular spacesuit operation to meet the environmental requirements given in section 4.3.9.2.

The extra-vehicular life support shall allow 4-hour periods of continuous separation from the LEM (three hours normal plus 1 hour contingency) for each crewman.

For initial missions, a total of [24] man-hours of extra-vehicular operation on the lunar surface shall be possible per mission. The back packs shall be rechargeable from the environmental control and electrical systems inside the CM and the LEM. *As a design objective, it shall be possible for crewman to recharge his back pack without assistance while standing on the lunar surface.* The time for complete recharge shall not exceed ___ hours.

4.3.9.1.5 Crew Support and Restraint. The support and restraint system in the CM and LEM shall:

a) provide adequate crew protection against all anticipated acceleration vectors including landing impact.

b) provide suitable restraints for crew functioning in a sub-gravity environment.

c) be adjustable for comfort, visibility, and accessibility to controls; and

d) accommodate any member of the crew wearing a space-suit pressurized or nonpressurized.

4.3.9.1.6 Sanitation and Personal Hygiene. A system for collection and disinfection of biological excretions shall be provided in the CM and in the LEM.

Precaution shall be taken to minimize contamination of the lunar surface by the Apollo crew or equipment. Biological wastes of the crew shall not be allowed to become a free residue in space or on the lunar surface. An effective method of confinement or sterilization prior to disposal on the lunar surface or in space shall be employed.

There shall be no requirement for sterilization of the Apollo spacecraft or launch vehicles, i.e., no requirements for sterile assembly of subsystems, no requirements for resistance to ethylene oxide, heat cycles, or other common techniques for reducing the number of viable micro-organisms.

4.3.9.1.7 Medical Supplies. The CM and LEM shall be equipped with first aid equipment, drugs, and medical supplies.

4.3.9.1.8 Bio-Medical Instrumentation. Equipment shall be provided to measure the following physiological parameters of each crewman on board the CM and LEM during the mission:

(a) Cardiovascular System
(b) [Respiration Rate]
(c) [Respiration Volume]
(d) [Blood Pressure]
(e) [Pulse Rate]
(n) ____________________

At least [1] of the parameters shall be recorded and telemetered in real time during stressful mission phases. The remaining parameters shall be monitored and recorded on board the spacecraft.

4.3.9.1.9 Radiation Dosimeter. Each crew member shall be equipped with an accurate, direct reading radiation dosimeter. The dosimeter shall register accumulated dosage and have a suitable warning device.

4.3.9.2 Environmental Control Systems. The CSM and LEM environmental Control Systems shall provide a conditioned atmosphere for the crews during manned phases, thermal control of all equipment where needed, connections for the space suits, and arrangements for recharging the portable life support systems.

4.3.9.2.1 Atmospheric Control Systems. The atmospheric gas supplies for the CM and for the LEM shall exceed the estimated requirements (metabolic + leakage + repressurization + recharge of back packs) by [50] percent. Provision shall be made for connection of the CM oxygen to the O_2 supply of the fuel cell. A supply of oxygen for use from the start of re-entry to touchdown shall be provided in the CM.

4.3.9.2.1.1 Circulation and Ventilation. Fans and blowers shall be provided for circulation of the CM and LEM atmospheres. Post-landing ventilation of the CM shall be provided.

4.3.9.2.1.2 Noxious and Toxic Gases/Particles. Provisions shall be made in the CM, LEM and space suits for the removal of particles and the control of noxious and toxic gases to permissible concentrations. *As a design objective, equipment shall be provided in the CM and LEM for automatic gas analysis.*

4.3.9.2.1.3 Pressures. After launch the partial pressures of oxygen in the CM, LEM and space suit atmospheres shall not be less than 160 mm Hg nor more than [380] mm Hg referenced to [70°] F dry bulb. The pressure ratios of any two total atmospheres of the CM, LEM, and spacesuits shall not exceed 2:1.

The pressure systems shall be capable of maintaining cabin pressures of 3.5 psia for [5] minutes in the CM, and 2 minutes in the LEM, with a hole in either pressure compartments not exceeding 0.5 inches in diameter.

4.3.9.2.1.4 Operative Temperatures. Air circulation, temperature and humidity of the CM, LEM and spacesuit atmospheres shall be controlled to meet the following Operative Temperatures:*

	Min.	Max.
CM		
LEM		
Spacesuit		

4.3.9.2.2 Thermal Control Systems. *As a design objective thermal control of external heat fluxes to the interiors of the CSM and LEM shall be passive and a function of the structural design and surface finish of the spacecraft.*

Thermal control of the internal heat load of the CSM and LEM shall be passive to the extent possible. Where the passive system does not meet environmental requirements, an active system with arrangements for positive thermal control shall be provided.

Maximum radiant heat exposure to the crew from cabin wall temperatures during launch and re-entry shall not exceed [18] BTU/ft^2/min.

The cooling systems shall provide thermal control for equipment. No systems, subsystems or components critical to completion of the mission shall be dependent on the cabin air temperature of the CM or LEM for thermal conditioning.

4.3.9.2.3 Meteoroid and Radiation Protection. Protection against meteoroid penetration and radiation shall be primarily a function of the structure of the spacecraft. Arrangement of equipment and crew

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*(Operative Temperatures shall be defined as in ___ assuming a skin temperature (t_s) of [92.3°F] and partial pressures of water vapor (P_w) between ___ min. and ___ max. mm Hg).

members in the CM and LEM shall be such as to enhance the structural protection under the environmental conditions listed in OMSF Program Directive M-DE 8020.008. The overall system shall limit radiation exposure to a maximum of [30] rems per mission exclusive of solar flares.

4.3.10 Crew Systems. The criteria governing the design of crew systems shall be as listed under section 4.3.1 and as follows:

4.3.10.1 Crew

4.3.10.1.1 Crew Complement. The Apollo crew shall consist of three astronauts selected from a larger trained group.

4.3.10.1.2 Crew Structure. There shall be an established order of command within the crew. Responsibility for execution of the detailed mission plan will normally be delegated to the Crew Commander by the IMCC. Delegation of on-board command responsibilities shall be made by the Crew Commander on the basis of appropriateness to mission function.

4.3.10.1.3 Training. The crew shall receive thorough training in the operation, test, maintenance and repair of on-board equipment and in the operation and conduct of required scientific experiments.

Each crew member shall be cross-trained to execute adequately all crew functions essential to survival.

4.3.10.2 Displays and Controls. Displays and controls in both the CM and LEM shall be designed to increase the probability of correct crew actions. To accomplish this, displays and controls shall be designed such that the crew can:

a) assess system status and trend,
b) compare actual with desired conditions,
c) determine and execute appropriate action, when required.

Consistency of information displays, control actions, and their relationships, shall be maintained within and between the CM and LEM.

The system shall incorporate the provisions for monitoring and analysis of critical system functions in such a manner that out-of-tolerance performance can be recognized and assessed, both on the ground and by the flight crew, utilizing on-board equipment as required in time for remedial action.

Active warning indicators shall be employed to alert the crew to out-of-tolerance conditions in all critical subsystems.

Displays and controls for both the CM and the LEM shall be designed to satisfy the requirements of section 4.4 and the following:

a) single-man performance of all critical functions in either vehicle is possible.

b) critical functions can be performed by a crewman wearing an inflated pressure suit.

c) *as a design objective, no significant lowering of the probability of crew safety shall occur when crew functions are performed by crewmen wearing inflated pressure suits.*

The design of controls shall be such that:

a) the astronaut can exercise precise and reliable control over system function.

b) the ratio of probabilities of "successful-control-operation" to "inadvertent-control-operation" is maximized.

Where possible, and where it is not beyond the response-time capabilities of the crew, provision shall be made for manual override of all automatic systems essential to mission success.

4.3.10.2.1 Visual Requirements. The general illumination within both vehicles shall be controllable to allow the accurate reading of all displays. Under all conditions, illumination shall be provided to allow the reading and interpretation of critical displays. The windows of the CM and LEM shall have the capability for variable light attentuation.

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4.4 Navigation, Guidance and Control

4.4.1 General

The Apollo space vehicle will contain three separate systems which will be located in the Instrument Unit of the Saturn V launch vehicle, in the CM and in the LEM. Each of the systems will perform the functions of guidance, navigation and control. These systems will direct the course of the vehicle (guidance), and determine its position in space (navigation). They will also maintain, at some commanded value, the vehicle attitude and the direction of the thrust vector (control). Stabilization of the vehicle to prevent excessive oscillatory motion in the presence of influences such as disturbing torques or structural bending is considered part of the control function.

The role of the launch vehicle, the CM, and the LEM systems in the normal LOR mission is listed in the following paragraphs.

a) The launch vehicle system will be capable of providing the functions of guidance, navigation and control for the Apollo Space Vehicle from earth launch to completion of injection into a lunar transfer trajectory.

b) The CM system will have the capability of guiding the space vehicle from earth parking orbit to completion of injection into a lunar transfer trajectory. The functions of guidance, navigation and control for the spacecraft after injection into a lunar transfer trajectory will be provided by the CM system. It will be used in making the necessary mid-course corrections both while the spacecraft is traveling to the Moon and later while the spacecraft is returning to the Earth. The CM system will be employed also in performing the insertion into lunar orbit and the injection from lunar orbit into earth transfer trajectory. Furthermore, the system will be used for maintaining the correct re-entry attitude of the CM as it approaches the Earth and directing the maneuvers of the CM after it re-enters the Earth's atmosphere and nears the landing site.

c) The LEM system furnishes the guidance, navigation and control of this module from its descent from lunar orbit to touchdown on the lunar surface and again from its launch from the lunar surface to rendezvous and docking with the CM.

Throughout the mission, the systems on board the space vehicle will work cooperatively with earth-based tracking and computation facilities. These facilities will have continuous information on the vehicle position and velocity which will be furnished the space vehicle in various phases of the mission as required. The earth-based facilities will also co-operate with the space vehicle systems in other ways, e.g., independent calculation of the direction and magnitude of the desired vector velocity before initiation of engine burns for midcourse corrections.

For implementing the guidance and navigation functions, each of the three onboard systems will use an inertial measurement unit (IMU) and a general-purpose digital computer. The systems in the CM and LEM also will be equipped with optical instruments and radars. In addition, the CM and LEM will be operated with crew participation whereas the operation of the equipment in the launch vehicle will be automatic.

For performing the control function, each of the three systems will use its stabilized platform which is part of the IMU. However, in both the CM and LEM, additional body-mounted position gyros will be provided for use when the platform is not operating. Also, for the purpose of vehicle stabilization, rate gyros and accelerometers (where required) will provide inputs to the control electronics.

4.4.2 Guidance and Control Profile

This section defines the Apollo mission profile from a guidance and control viewpoint. The mission is divided into the following phases: (1) earth launch to earth parking orbit, (2) earth parking orbit to injection into lunar transfer trajectory, (3) lunar transfer trajectory, (4) lunar operations, (5) earth transfer trajectory, and (6) re-entry.

4.4.2.1 Earth Launch to Earth Parking Orbit. The powered flight of the three stages of the Saturn V launch vehicle (S-IC, S-II and S-IVB), from launch to insertion of the S-IVB/Spacecraft combination into earth parking orbit, shall be directed by the launch vehicle systems. The initial phase of the flight, that powered by the S-IC stage, shall be flown "open loop" in the guidance sense; that is, the steering commands are given in accordance with a pre-determined program. The following phases, those powered by the S-II and S-IVB stages, shall be flown with steering commands derived from measurements and computations by the launch vehicle guidance system. For both the S-IC and the S-II stages, the engine-cutoff commands shall be initiated by sensors indicating propellant depletion. The cutoff of the S-IVB stage shall be commanded by the guidance system when it determines that the vehicle has achieved the proper conditions for the desired orbit. After cutoff, the earth-based support system shall verify the attained orbit.

For each of the three stages, stabilization and control shall be provided by the launch vehicle control system. Roll control and direction of the thrust vector shall be achieved in the S-IC and S-II by positioning their four gimbaled engines. With the S-IVB, direction of the thrust vector shall be achieved by positioning the single gimbaled engine, and roll control shall be provided by the reaction jets. Stability of the vehicle shall be assured by shaping networks in the control system and rate gyros, angle of attack sensors, and accelerometers as required.

4.4.2.2 Earth Parking Orbit to Injection into Lunar Transfer Trajectory

While the S-IVB/Spacecraft is in earth parking orbit, attitude control shall be provided by the S-IVB reaction control system. During this period, optical measurements shall be made by the crew members for alignment of the IMU in the CM for an on-board determination of the parking orbit parameters. To assure a vehicle attitude suitable for optical measurements, the launch vehicle control system shall be capable of executing attitude commands generated by the crew in the CM. This capability can be utilized also after injection into lunar transfer trajectory to provide favorable attitude orientation in preparation for the turnaround and docking maneuver.

Before the second ignition of the S-IVB engine, with the launch vehicle system providing guidance through injection, data stored in the launch vehicle digital computer shall be evaluated by the ground facilities and updated if required. This procedure shall reflect the best known values of the initial conditions for injection into the lunar transfer trajectory. The launch vehicle system shall be capable, upon command from the ground, of automatically transmitting and receiving data. The launch vehicle IMU shall not require realignment after launch.

With the CM system providing guidance through injection, the operation prior to the second ignition of the S-IVB engine shall be similar to that stated before. Exception shall be made in those cases where crew participation can be used with advantage.

4.4.2.3 Lunar Transfer Trajectory. After satisfactory injection of the S-IVB/Spacecraft into lunar transfer trajectory has been verified by the CM system and ground tracking and computing facilities, the initial turnaround and docking of the CSM shall be accomplished. Control of the CSM during this maneuver shall be by the crew members. As part of this operation, the S-IVB and the Instrument Unit shall be jettisoned.

While the spacecraft is traveling along the lunar transfer trajectory, several mid-course velocity corrections will be made to attain the desired flight path to the vicinity of the Moon. Data from optical measurements made by the crew members shall be used by the CM digital computer to calculate the required velocity corrections. These results shall be checked by independent measurements and calculations made on the ground.

The crew members shall have the capability of using the optical equipment in the CM for in-space re-alignment of the IMU prior to powered flight periods. Attitude reference shall be provided by the IMU during powered flight; however, during other periods, the crew members shall have the capability of utilizing either the IMU reference or a body-mounted attitude reference (three position gyros). The body-mounted reference system, in conjunction with a longitudinal accelerometer, rate gyros, and the astronaut's displays and controls, can be used also as a back-up for the IMU during engine burns.

Attitude control and stabilization of the spacecraft, from separation of the S-IVB until separation of the CM from the SM prior to re-entry into the Earth's atmosphere, shall be provided by the CM control system and the SM reaction control jets. Thrust vector control shall be provided by the CM control system by positioning the single gimbaled engine on the SM.

After the last mid-course correction, additional optical measurements shall be made to up-date trajectory information in preparation for insertion into a circular lunar parking orbit. These data shall be used by the on-board digital computer to perform the calculations required for the insertion maneuver. These results shall be compared with measurements and computations by ground facilities to determine the best estimate of the initial conditions for insertion.

4.4.2.4 Lunar Operations. After insertion of the CSM/LEM into a lunar parking orbit and before separation of the LEM from the CM, various functions shall be performed in preparation for LEM descent. The ephemeris of the lunar parking orbit shall be determined, utilizing both optical measurements from the CM and radar measurements by earth-based tracking stations. Optical measurements shall be made by the crew members in the LEM for erection and coarse alignment of its IMU. Data pertinent to the LEM guidance and control, including spacecraft ephemeris data and initial conditions for the lunar descent, shall be transferred from the CM to the LEM digital computer.

After separation of the LEM from the CM, the crew members in the LEM shall make optical measurements for fine alignment of the LEM IMU. The LEM attitude control system, using the stable platform of the IMU as a reference, shall properly orient the LEM for descent to the lunar surface. Commands to ignite the LEM engine and to direct the course of the LEM during engine burning shall be provided by the LEM guidance system. These commands shall be calculated by the digital computer utilizing inputs from the IMU and the radar. The two astronauts shall be able to assume manual control for the hover and translation maneuvers and the descent to the lunar surface. Throughout the descent, it shall be possible to abort the mission and return to lunar orbit. *Also, as a design objective, the LEM shall be capable of performing a descent from lunar orbit and of soft-landing at a pre-selected landing point on the lunar surface, without the participation of the LEM crew except, if necessary, for initial alignment of the LEM IMU prior to separation from the CM.*

Prior to launch from the lunar surface, the LEM crew members shall align the IMU utilizing the optical system. The measurement and computation facilities on the Earth, in the CM and in the LEM shall be used as appropriate, to determine pre-launch conditions such as time of launch and refined CSM ephemeris data.

The launch and ascent of the LEM into lunar orbit shall be directed by the LEM primary guidance system. However, an alternate, simple and self-contained means of LEM guidance shall be provided in event of failure of the LEM primary guidance at any time after lunar landing. *Additional provisions for returning the LEM to lunar orbit, which are now specified as design objectives, are the capability of the CM to radio-guide the LEM, by voice and/or automatic radio command into lunar orbit and the capability of the CM to signal the time of launch to the LEM and subsequently range and track the LEM as an aid to rendezvous.*

The LEM shall be the primary vehicle for effecting LEM rendezvous and docking with the CM in lunar orbit; however, in the event of LEM abort into lunar orbit, the CM and its crew member shall have the capability for rendezvous with the LEM.

4.4.2.5 <u>Earth Transfer Trajectory.</u> After the LEM has docked with the CM and the two LEM crew members have returned to the CM, the LEM shall be jettisoned and the CM shall be injected into an earth transfer trajectory. Guidance, navigation and control used to achieve the desired return trajectory, including mid-course corrections, shall be performed in the same manner as during the lunar transfer.

4.4.2.6 Reentry. After the last mid-course correction has been made, a number of scheduled navigational sightings shall be taken to reduce the uncertainty of conditions that will exist when the reentry maneuver starts. Prior to reentry, the SM shall be jettisoned and its trajectory modified to assure that the SM will not collide with the CM during reentry. Maneuvering during reentry shall be achieved by controlling the roll attitude about the stability axis of the CM, thereby controlling the orientation of its lift vector. Commands to the stabilization and control system shall be generated by the CM guidance system. Arrival at the point of parachute deployment completes the guidance, navigation and control functions.

4.4.3 Design Requirements

Requirements of a general nature which influence the design of the guidance systems in the launch vehicle, CM and LEM are listed in this section.

4.4.3.1 Data from on-board measurements pertinent to guidance and navigation shall be transmitted to earth-based facilities to perform computations that are the same as those performed on the space vehicle. Results of on-board computations shall be transmitted to earth-based facilities for evaluation and/or verification. Independent earth-based measurements and computations shall be used in evaluation and verification procedures.

4.4.3.2 The CM system shall have the capability of guiding the space vehicle from earth parking orbit to completion of injection into a lunar transfer trajectory.

4.4.3.3 The astronauts shall have the capability of commanding the attitude of the S-IVB and spacecraft from the CM during earth parking orbit for the purpose of making optical measurements, and after injection into lunar transfer trajectory, for favorable attitude reorientation in preparation for the turnaround and docking maneuvers.

4.4.3.4 The design of the CM and LEM guidance and control systems shall be such that the astronauts have the capability of selecting the mode of operation of each subsystem.

4.4.3.5 The astronauts shall be capable of manually interrupting the automatic functions in the CM and LEM guidance systems except for those essential to automatic abort.

4.4.3.6 The design of the CM and LEM guidance system shall be such that the astronauts have the capability of manually updating the parameters used for guidance computations.

4.4.3.7 The CM shall contain displays and manual controls to enable the astronauts to operate the CM or SM reaction jets for translation and attitude control of the spacecraft.

4.4.3.8 Major subassemblies of the CM and LEM guidance and control systems shall be physically interchangeable wherever practicable.

4.4.3.9 The capability of in-flight repair of the IMU in the CM and/or the LEM shall not be required. This shall not preclude the possibility of interchanging the IMU's between the LEM and CM.

4.4.3.10 The LEM shall contain displays and manual controls to enable the astronauts to operate the LEM reaction jets for translation and attitude control of the LEM.

4.4.3.11 The design of the CM guidance and control systems shall be such that a single crew member can return the CM safely to Earth from any point in the mission profile.

4.4.3.12 The LEM shall be the primary vehicle for effecting LEM rendezvous and dock with the CM in lunar orbit. The CM and its crew member shall have the capability for rendezvous with the LEM and rescue of the LEM crew in the event of LEM abort into lunar orbit.

This capability shall not be limited in any way by CM guidance and control capability; the only limitation shall be CM propulsion available for rescue.

4.4.3.13 *As a design objective, the design of the CM guidance and control system shall be such that, in case it is necessary to abandon the mission, the CM can be returned safely to Earth by ground-based radio command - by request of the crew if they are functioning or without active crew participation if they are incapacitated.*

4.4.3.14 The LEM shall have the capability, independent of lunar-based landing aids, of landing at a preselected point on the lunar surface with a circular error probable (CEP) of one-half mile without necessitating expenditure of the hover time provided for landing site selection.

4.4.3.15 *The LEM shall have additional capability of landing at a pre-selected landing point through the use of a lunar-based beacon or equivalent, with a design objective CEP of 100 feet.*

4.4.3.16 *As a design objective, the LEM shall be capable of performing a descent from lunar orbit and of soft-landing at a pre-selected landing point on the lunar surface without the participation of the LEM crew except, if necessary, for initial alignment of the LEM Inertial Measurement Unit prior to separation from the CM.*

4.4.3.17 The design of the guidance and control system for the LEM shall be such that it is possible to abort the mission at any point in the descent of the LEM and return the LEM to lunar orbit for rescue.

4.4.3.18 An alternate, simple and self-contained means of LEM guidance shall be provided in event of failure of the LEM primary guidance system at any time subsequent to landing. This shall not preclude the use of a CM-LEM launch signal command or CM-LEM voice links.

4.4.3.19 *As a design objective, the mechanization of the CM and the LEM shall be such that the CM can signal the time of launch to the LEM and subsequently range and track the LEM for the purpose of relative CM-LEM position determination and as an aid to rendezvous.*

4.4.3.20 *As a design objective, the CM and LEM mechanization shall be such that it is possible for the CM to radio-guide the LEM, by voice and/or automatic radio command, into lunar orbit.*

4.4.4 System Performance Requirements

4.4.4.1 Guidance and Navigation Requirements. This section contains the set of position and velocity uncertainties* that shall be used for design purposes. They include the effects of cumulative guidance and navigation errors (equipment errors and initial condition uncertainties). Such effects as vehicle performance deviations and thrust vector misalignment are not included, since these errors are implicit in the acceleration measurements and can, for all practical purposes, be eliminated during engine burns. These uncertainties are valid unless vehicle deviations exceed the capability of the guidance scheme. They reflect the requirements on the launch vehicle, CM and LEM systems and the earth-based support systems.

The following target referenced coordinate system will be used:

Range Axis (R) - collinear with the desired velocity vector.

Normal Axis (N) - perpendicular to the Range component and contained in the desired orbital plane.

Track Axis (T) - perpendicular to Range and Normal.

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*The terms uncertainty and deviation as used in this section are defined as follows:

Uncertainity - Difference between the estimated and actual position and velocity.

Deviation - Difference between the estimated and desired position and velocity.

The one sigma allowable uncertainties for each phase of the mission are:

4.4.4.1.1 Insertion into earth parking orbit (using the IU IMU)

R	[350]	ft.
T	[680]	ft.
N	[500]	ft.
$\dot{R}$	[0.95]	ft/sec
$\dot{T}$	[1.85]	ft/sec
$\dot{N}$	[1.65]	ft/sec

4.4.4.1.2 Start of injection into lunar transfer trajectory after 4.5 hours in earth parking orbit (based only on earth tracking data).

R	[310]	ft.
T	[300]	ft.
N	[340]	ft.
$\dot{R}$	[0.63]	ft/sec
$\dot{T}$	[0.65]	ft/sec
$\dot{N}$	[0.88]	ft/sec

4.4.4.1.3 Injection into lunar transfer trajectory

a) using the IU IMU

R	[1,440]	ft.
T	[1,920]	ft.
N	[1,440]	ft.
$\dot{R}$	[10.3]	ft/sec
$\dot{T}$	[13.7]	ft/sec
$\dot{N}$	[10.3]	ft/sec

b) using the CM IMU

R	[1,500]	ft.
T	[1,990]	ft.
N	[1,500]	ft.
$\dot{R}$	[11.0]	ft/sec
$\dot{T}$	[14.6]	ft/sec
$\dot{N}$	[11.0]	ft/sec

4.4.4.1.4 Start of insertion into lunar parking orbit
(position, three components)
(velocity, three components)

4.4.4.1.5 Insertion into lunar parking orbit
(position, three components)
(velocity, three components)

4.4.4.1.6 Start of insertion of LEM into transfer orbit
(position, three components)
(velocity, three components)

4.4.4.1.7 Insertion of LEM into transfer orbit
(position, three components)
(velocity, three components)

4.4.4.1.8 Pericynthion (LEM)

a) during first orbit (180°)
(position, three components)
(velocity, three components)

4.4.4.1.9 Hover point* (without a lunar-based beacon or its equivalent)

a) descent started during first orbit
(position, three components)
(velocity, three components)

4.4.4.1.10 Hover point (with a lunar based beacon or its equivalent)

a) descent started during first orbit
(position, three components)
(velocity, three components)

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*A reference point located 1,000 feet above the desired lunar landing site. At this point, the LEM shall nominally have zero velocity relative to the lunar surface.

4.4.4.1.11 Insertion of LEM into ascent transfer orbit
(position, three components)
(velocity, three components)

4.4.4.1.12 End of last LEM mid-course correction maneuver
(position, three components)
(velocity, three components)

4.4.4.1.13 Start of injection into earth transfer trajectory
(position, three components)
(velocity, three components)

4.4.4.1.14 Injection into earth transfer trajectory
(position, three components)
(velocity, three components)

4.4.4.1.15 Vacuum perigee*

N	[2]	nautical miles

4.4.4.1.16 Parachute Deployment
(position, two components)

4.4.4.2 Attitude Control Requirements. This section specifies the attitude control requirements necessary to perform the mission. These specifications reflect the requirements on the S-IVB/IU, CSM and LEM stabilization and control systems and reaction control jets. Although the systems must have this capability, it should not be inferred that they must operate with the same degree of accuracy during the entire mission.

Turning and translation rates must be controlled to values no larger than those listed in Tables 4.4-1 and 4.4-2. These rates place upper limits on the minimum impulse capabilities of the reaction control systems. Table 4.4-1 also contains the permissible deviations from a commanded attitude.

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* The closest point that a re-entering vehicle would pass the center of the Earth, assuming the Earth to be a point mass with no atmosphere.

4.4.5 Equipment Performance Capabilities

The equipment performance capabilities cited in this section represent the standards to which the subsystems shall be designed. These standards satisfy the system performance requirements stated in Section 4.4.4.

4.4.5.1 Launch Vehicle Equipment Performance Capabilities

4.4.5.1.1 Inertial Measurement Unit (IMU). This instrument shall provide launch vehicle attitude information, a space-stabilized coordinate system and the three velocity components determined from integrated acceleration measurements.

4.4.5.1.2 Digital Computer. This general purpose digital machine shall have the capability of performing all guidance problem computations, vehicle sequencing, and timing through injection into lunar transfer trajectory, and shall conduct diagnostic tests of itself and checkout routines of other launch vehicle subsystems. The characteristics of this computer shall include the following:

Data word length	[26]	bits
Instruction word length	[13]	bits
Add time*, accuracy	[84]	μsec, [26] bits
Multiply time*, accuracy	[336]	μsec, [24] bits
Divide time	[672]	μsec, [24] bits
Storage capacity**	[8,192 26-bit]	words

4.4.5.2 CM Equipment Performance Capabilities

4.4.5.2.1 Sextant. This instrument shall be used for mid-course angle measurements, star elevation measurements, and star tracking for IMU alignment. The RMS error of angular measurements after quantization shall be no more than [0.05] milliradians.

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*Based on add-subtract and multiply-divide simultaneously.
**Expandable to [24,576 26-bit] words maximum.

4.4.5.2.2 Scanning Telescope. This instrument shall be used for acquisition and identification of celestial bodies, the tracking of landmarks, and as a back-up for the sextant during the IMU alignments. The RMS error of angular measurements after quantization shall be no more than [0.3] milliradians.

4.4.5.2.3 Inertial Measurement Unit (IMU). This instrument shall provide CM attitude information, a space-stabilized coordinate system and the three velocity components (integrated acceleration measurements) due to both SM thrust and CM re-entry deceleration.

4.4.5.2.4 Body-Mounted Inertial Components. The CM system shall contain the following body-mounted inertial components:

a) Body-Mounted Integrating Gyros. These gyros shall be capable of providing an attitude reference whenever the IMU is not in operation. They shall also be capable of operation as a back-up for the body-mounted rate gyros.

b) Body-Mounted Rate Gyros. These gyros shall be capable of measuring the rates of change of attitude.

c) Longitudinal Accelerometer. This accelerometer shall be capable of determining the velocity increment component along the longitudinal axis of the CM during engine burns and re-entry.

In-flight replacement of the accelerometer and of individual gyros shall be possible without recalibration.

4.4.5.2.5 Computer. This general purpose digital machine shall have the capability of performing all CM guidance problem computations, vehicle sequencing and timing, and shall conduct diagnostic tests of itself and checkout routines of other CM sub-systems. The characteristics of this computer shall include the following:

Data word length	______ bits
Instruction word length	______ bits
Add time	______ μsec
Multiply time	______ μsec
Divide time	______ μsec
Permanent storage capacity	______ words
Temporary storage capacity	______ words

4.4.5.2.6 Rendezvous Radar. The CSM cooperative rendezvous radar shall be capable of measuring range, range-rate, angle and angle-rate relative to either the LEM or a lunar based beacon. The functional characteristics of this radar shall include the following:

Function	Minimum	Maximum	Accuracy (3δ)
Range	[5] ft.	[400] n. mi.	±[1]% or ±[5] ft.
Range Rate	[1] fps	[±4,800] fps	±[1]% or ±[1] fps
Angle			bias [8] mr, random [2] mr
Angle Rate		[±15] mr/sec	[±0.2] mr/sec

Technical specifications are given in Section 4.5

4.4.5.2.7 Lights (running and flashing). These devices shall be used as optical tracking aids between the CM and LEM. The LEM crew members shall be able to identify the CM without optical aids and in the presence of any stellar background, at a distance of ______ nm.

4.4.5.3 LEM Equipment Performance Capabilities

4.4.5.3.1 Alignment Telescope. This instrument shall be used for star tracking for IMU alignment, and tracking of land-marks. The RMS error of angular measurements after quantization shall be no more than ______ milliradians.

4.4.5.3.2 Inertial Measurement Unit (IMU). This instrument shall provide LEM attitude information, a space-stabilized coordinate system, and the three velocity components determined from integrated acceleration measurements.

4.4.5.3.3 Body-Mounted Inertial Subsystem
(To be included in a later edition.)

4.4.5.3.4 Computer. This general purpose digital machine shall have the capability of performing all LEM guidance problem computations, vehicle sequencing, and timing trajectory, and shall conduct diagnostic tests of itself and checkout routines of other LEM subsystems. The characteristics of this computer shall include the following:

Data word length	______	bits
Instruction word length	______	bits
Add time	______	μsec
Multiply time	______	μsec
Divide time	______	μsec
Permanent storage capacity	______	words
Temporary storage capacity	______	words

4.4.5.3.5 Rendezvous Radar. The LEM cooperative rendezvous radar shall be capable of measuring range, range-rate, angle and angle-rate relative to either the CSM or a lunar based beacon. The functional characteristics of this radar shall include the following:

Function	Minimum	Maximum	Accuracy (3δ)
Range	[5] ft.	[400] n. mi.	±[1] % or ±[5] ft.
Range Rate	[1] fps	[±4,800] fps	±[1] % or ±[1] fps
Angle			bias [8] mr, random [2] mr
Angle Rate		[±15] rm/sec	[±0.2] mr/sec

Technical specifications are given in Section 4.5.

4.4.5.3.6 Landing Radar. The LEM landing radar shall be capable of measuring range and range rate relative to the lunar surface. The functional characteristics of this radar shall include the following:

Function	Minimum	Maximum	Accuracy (3δ)
Range	[5] ft.	[20,000] ft.*	±[1] % or ±[5] ft.
Range Rate	[-500] fps	[+2,200] fps	±[1] % or ±[1] fps

4.4.5.3.7 Lights (running and flashing). These devices shall be used as optical tracking aids between the CM and LEM. The CM crew member shall be able to identify the LEM, without optical aid and in the presence of any stellar background, at a distance of ______ nm.

*The landing radar must be capable of being checked out at altitudes up to [70,000] ft.

Table 4.4-1
Attitude Control Requirements

		Turning Rate Limit (min/sec)			Attitude Deviation Limit (deg)		
		Roll	Pitch	Yaw	Roll	Pitch	Yaw
Communications (using directional antenna)	CSM						
	LEM						
ΔV Orientation	CSM						
	LEM						
Optical Measurements from CM	during earth orbit	[2]	[2]	[2]	Manual Control		
	during lunar and earth transfer trajectory	[1.2]	[1.2]	[1.2]			
	during lunar orbit	[1.2]	[1.2]	[1.2]			
Optical Measurements from LEM							

Table 4.4-2
Attitude Control Requirements
(for docking)

		Turning Rate Limit (min/sec)			Translation Rate Limit (ft/sec)			Attitude Deviation Limit (deg)		
		Roll	Pitch	Yaw	X	Y	Z	Roll	Pitch	Yaw
Quiescent Vehicle	Transposition				Not Applicable					
	Lunar Orbit (CSM quiescent)									
	Lunar Orbit (LEM quiescent)									
Active Vehicle	Transposition							Manual Control		
	Lunar Orbit (LEM active)									
	Lunar Orbit (CSM active)									

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4.5 Space Vehicle Communications

4.5.1 Scope

This section contains the specifications for the operational communications and tracking subsystems in the launch vehicle and spacecraft required to provide the necessary flow of data and information between the space vehicle and the ground system, between modules of the spacecraft when separated and between the astronauts. Specifications for research and development subsystems that may be carried by the space vehicle are not contained in this section. Specifications are grouped by space vehicle module and subsystem.

Specifications for the ground-based subsystems that operate with the space vehicle communication subsystems are given in Sections 4.7 and 4.8.

4.5.2 S-IC and S-II Stage Communications

4.5.2.1 Telemetry (Space-to-Ground Data) Subsystem

a) Functional Requirements. The S-IC and S-II stage telemetry subsystems shall be capable of transmitting to the LCC checkout data during prelaunch phases of the mission and subsystem status data during powered flight.

b) Technical Characteristics. The S-IC and S-II stages shall each be provided with operationally separate and independent telemetry subsystems. The telemetry transmitters shall be capable of transmitting subsystem status measurements and checkout data.

One system in each stage shall be a Digital Data Acquisition System (DDAS) and shall be used for automatic checkout. It shall be possible to send the data from the launch vehicle DDAS to ground checkout equipment over the umbilical cable.

The characteristics of the telemetry transmitting subsystems shall be as shown in Table 4.5-1.

The telemetry transmitter(s) in the S-IC stage shall radiate from antenna subsystems on the S-IC stage. The telemetry transmitter(s) in the S-II stage shall radiate from antenna subsystems on the S-II stage. The characteristics of the antenna subsystems shall be as shown in Table 4.5-3.

4.5.2.2 Command-Destruct Subsystem

a) Functional Requirements. The S-IC and S-II stages shall each be provided with a command-destruct receiving subsystem, capable of continuous data reception during launch.

b) Technical Characteristics. Two sets of identical command receivers, decoders, and their power supplies shall be provided in both the S-IC and S-II stages.

The characteristics of the command-destruct receiving subsystems shall be as shown in Table 4.5-2.

The command-destruct receiving subsystem shall utilize [one] omni-directional antenna subsystem(s) in each powered stage with characteristics as shown in Table 4.5-3.

4.5.2.3 Transponder Subsystem

(To be included in a later edition.)

4.5.3 S-IVB Stage and Instrument Unit (IU) Communications

4.5.3.1 Telemetry (Space-to-Ground Data) Subsystem

a) Functional Requirements. The telemetry subsystem of both the S-IVB stage and the IU shall be capable of transmitting checkout data to the LCC during the prelaunch phase and either checkout or subsystem status monitoring data to the Earth after lift-off.

b) Technical Characteristics. The S-IVB stage and IU shall each be provided with operationally separate and independent telemetry subsystems.

Both the S-IVB stage and the IU shall be equipped with a Digital Data Acquisition System (DDAS), which shall be used for remote automatic checkout during prelaunch. It shall be possible to send the DDAS data to the ground checkout equipment over the umbilical cable. After lift-off and during Earth orbit phases of the mission, it shall be possible to send checkout data over a radio link.

The telemetry subsystem in the IU shall have the capability of transmitting information to the Earth for verification of the data received by the up-data link subsystem.

The characteristics of the telemetry transmitting subsystems shall be as shown in Table 4.5-1.

The characteristics of the antenna subsystems for the telemetry subsystems of the S-IVB and the IU shall be as shown in Table 4.5-3.

4.5.3.2 Command-Destruct Subsystem. The command-destruct subsystem, as specified in section 4.5.2.2 for the S-IC and S-II stages, shall be provided in the S-IVB stage.

The characteristics of the command-destruct receiving subsystem shall be as shown in Table 4.5-2.

This subsystem shall utilize [one] omni-directional antenna subsystem(s) with characteristics as shown in Table 4.5-3.

4.5.3.3 Up-Data Link (Ground-to-Space Data) Subsystem

a) Functional Requirements. A receiving subsystem shall be provided in the IU to receive ground data (e.g., guidance and checkout) for insertion into the launch vehicle computer.

It shall be possible to verify data received by this subsystem by transmitting information to Earth over the IU telemetry subsystem.

b) Technical Characteristics. [One] receiver and decoder shall be provided in the IU.

The characteristics of the receiving subsystems shall be as shown in Table 4.5-2. The subsystem shall utilize an antenna subsystem in the IU with characteristics as shown in Table 4.5-3.

4.5.3.4 Transponder Subsystem

a) Functional Requirements. The IU shall be provided with a transponder subsystem which will permit angle, range [and velocity] tracking by earth-based tracking systems from launch through insertion into Earth parking orbit. *As a design objective the transponder subsystem of the IU shall permit angle and range tracking by suitably equipped ground stations from insertion into Earth orbit through jettison of the S-IVB/IU and for ____ minutes thereafter.*

b) Technical Characteristics. One transponder in the IU shall be capable of operating with earth-based pulse radar systems. The characteristics of the transponder transmitting and receiving ing subsystems shall be as shown in Tables 4.5-1 and 4.5-2, respectively.

[One transponder in the IU shall be capable of operating with an earth-based CW radio interferometer system. The transponder transmitting and receiving subsystems shall have characteristics as shown in Tables 4.5-1 and 4.5-2, respectively.]

The characteristics of the antenna subsystem(s) in the IU to be used by these subsystems shall be as shown in Table 4.5-3.

4.5.3.5 [Radar Altimeter Subsystem]

a) Functional Requirements. [The IU shall be provided with a radar altimeter subsystem to aid the earth-based facilities in determining the trajectory of the space vehicle.]

b) Technical Characteristics

(To be included in a later edition.)

4.5.4 Command and Service Module (CSM) Communications

The distribution of communication equipment between the CM and the SM shall be made so that:

a) the communication functions required to be performed after separation of the CM from the SM can be performed by equipment in the CM; and

b) equipment that must be maintained in flight is located in the CM.

Equipments used for communications with the Earth can be divided by their primary use in the near-earth and deep-space phases of the mission. This division shall not preclude their use in both phases whenever feasible.

4.5.4.1 Voice Communication Subsystem. The voice communication subsystem shall be capable of providing two-way service within the CM and between the CM and other operational units during operational phases as detailed below. For voice communications with the Earth, the near-earth equipments operate in the VHF band, and the deep-space equipments operate in the S-band. HF equipment shall also be provided for use during recovery operations. Facilities shall be included for storage and delayed readout of voice information.

4.5.4.1.1 VHF Voice Subsystem

a) Functional Requirements. The VHF subsystem shall be capable of providing two-way voice communications with: (1) the Earth during the near-earth phases of the mission including the recovery forces during the landing and post-landing phases, (2) an astronaut outside of the CM, and (3) the LEM (when the CM and LEM are in line-of-sight). The VHF voice subsystem shall also be capable of keyed operation in an emergency mode.

b) Technical Characteristics. The VHF subsystem shall consist of [one] transmitting subsystem(s) with characteristics as shown in Table 4.5-4A, and of [one] receiving subsystem(s) with characteristics as shown in Table 4.5-5. These shall utilize a common antenna subsystem, with characteristics as shown in Table 4.5-6.

4.5.4.1.2 HF Subsystem

a) Functional Requirements. The HF subsystem shall be capable of providing two-way voice communications with the recovery forces during the post-landing phase. The HF subsystem shall be capable of manually keyed CW operation in an emergency mode. The HF subsystem shall also be capable of operating as a beacon to aid the recovery forces.

b) Technical Characteristics. The HF subsystem shall be capable of operating with the HF equipment of the recovery forces. A minimum of [one] HF channel shall be provided. The characteristics of the HF subsystem shall be as given in Tables 5.4-4A and 4.5-5. The system shall utilize an antenna subsystem, with characteristics as shown in Table 4.5-6. It shall be possible to operate the VHF and HF voice subsystems simultaneously as well as separately. During simultaneous operation, means shall be provided for selection of the better of the two received signals.

4.5.4.1.3 S-Band Subsystem

a) Functional Requirements. The S-band subsystem shall be capable of providing duplex voice communications with the Earth during the deep-space phases of the mission. The S-band subsystem shall be capable of providing manually keyed operation for emergency communications with the Earth.

b) Technical Characteristics. The S-band voice subsystem shall have several modes of operation. These modes differ in the modulation characteristics of the signal and the choice of antenna subsystems. The transmitting characteristics shall be as shown in Table 4.5-4B. The receiving characteristics shall be as shown in Table 4.5-5. The characteristics of the antenna subsystems shall be as given in Table 4.5-6.

4.5.4.1.4 Interior Voice Communications Subsystem

a) Functional Requirements. The interior communications subsystem shall provide service among crew members within the CM.

b) Technical Characteristics
(To be included in a later edition.)

4.5.4.2 Telemetry (Space-to-Ground Data) Subsystem. The telemetry subsystem shall provide data transmission service from the CM to the Earth, including facilities for storage and delayed readout of data.

The telemetry subsystem shall have the capability of transmitting information to the Earth for verification of the data received by the up-data link subsystem.

4.5.4.2.1 VHF Subsystem

a) Functional Requirements. The VHF subsystem shall be capable of providing service to the Earth during the near-earth phases of the mission. The VHF telemetry signal shall also be capable of use for spacecraft acquisition by the ground equipment.

b) Technical Characteristics. The VHF subsystem shall consist of [one] transmitting set(s) with characteristics as shown in Table 4.5-4A. It shall utilize an antenna subsystem with characteristics as shown in Table 4.5-6.

4.5.4.2.2 S-Band Subsystem

a) Functional Requirements. The S-band subsystem shall be capable of providing telemetry service to the Earth during the deep-space phases of the mission.

b) Technical Characteristics. The S-band subsystem's transmitting characteristics shall be as shown in Table 4.5-4B. It shall utilize the antenna subsystems with characteristics as shown in Table 4.5-6.

4.5.4.3 Up-Data Link (Ground-to-Space Data) Subsystem. The CM shall incorporate an up-data link subsystem for the reception of data from the Earth. Means shall be provided in the up-data link subsystem to distinguish between command data and non-command data. It shall be possible to verify data received at the CM by transmission of information over the CM telemetry subsystem to the Earth.

4.5.4.3.1 UHF Data Subsystem

a) Functional Requirements. The UHF subsystem shall be capable of providing service from the Earth to the CM during the near-earth phases of the mission.

b) Technical Characteristics. The UHF subsystem shall consist of [one] receiving set(s) with characteristics as shown in Table 4.5-5. It shall utilize an antenna subsystem with characteristics as shown in Table 4.5-6.

4.5.4.3.2 S-Band Subsystem

a) Functional Requirements. The S-band subsystem shall be capable of providing service from the Earth to the CM during the deep-space phases of the mission.

b) Technical Characteristics. The S-band subsystem's receiving characteristics shall be as shown in Table 4.5-5. It shall utilize the antenna subsystems with characteristics as shown in Table 4.5-6.

4.5.4.4 LEM-to-CSM Data Subsystem

a) Functional Requirements. The LEM-to-CSM data subsystem shall provide reception and storage at the CSM of data from the LEM. Delayed readout of stored data shall be provided for transmission to Earth over facilities described in paragraph 4.5.4.2.2.

b) Technical Characteristics.
(To be included in a later edition.)

4.5.4.5 CSM-to-LEM Data Subsystem

a) Functional Requirements. *As a design objective, the CSM-to-LEM data subsystem shall provide data transmission service from the CSM to the LEM.*

b) Technical Characteristics
(To be included in a later edition.)

4.5.4.6 Transponder Subsystem

4.5.4.6.1 Earth-Tracking. The CSM shall be equipped with transponders to permit tracking by the tracking systems based on Earth as specified in Sections 4.6 and 4.8.

4.5.4.6.1.1 Radar Transponders

a) Functional Requirements. The radar transponders shall permit angle and range tracking by the Earth-based radars during the near-Earth phases of the mission.

b) Technical Characteristics. (One) transponder in the CM shall be capable of operating with an Earth-based pulse radar system. The characteristics of the transponder transmitting and receiving subsystems shall be as shown in Tables 4.5-4A and 4.5-5 respectively. The characteristics of the antenna subsystem to be used by this transponder shall be as shown in Table 4.5-6.

4.5.4.6.1.2 S-Band Transponders

a) Functional Requirements. The S-band subsystem shall permit angle, range and range-rate tracking by the earth-based system during the deep-space phases of the mission, except when the CSM is obscured by the Moon.

b) Technical Characteristics. The transmitting and receiving characteristics of the S-band transponders shall be as shown in Tables 4.5-4B and 4.5-5, respectively. These shall utilize the antenna subsystems with characteristics as shown in Table 4.5-6.

4.5.4.6.2 LEM-Radar Transponder

a) Functional Requirements. The CSM shall be equipped with a transponder to permit tracking of the CSM by a radar in the LEM as specified in Section 4.5.5.8.

b) Technical Characteristics
(To be included in a later edition.)

4.5.4.7 CSM Tracking Subsystem

a) Functional Requirements. The CSM shall be equipped with a radar capable of tracking the LEM provided with a transponder as specified in Section 4.5.5.7.2. The performance characteristics of the CSM radar shall be as specified in Section 4.4.5.2.6.

b) Technical Characteristics.
(To be included in a later edition.)

4.5.4.8 Recovery Beacon

4.5.4.8.1 VHF Recovery Beacon

a) Functional Requirements. The CM shall be equipped with a VHF beacon to permit direction finding by the recovery forces as an aid in determining the landing location of the CM.

b) Technical Characteristics. The CM beacon shall be compatible with the VHF radio tracking equipment used by the recovery forces. It shall have the characteristics shown in Table 4.5-4A.

The beacon shall utilize an antenna subsystem with characteristics as shown in Table 4.5-6.

4.5.4.8.2 HF Recovery Beacon

a) Functional Requirements. The CM shall be equipped with a HF beacon to permit direction finding by the the recovery forces as an aid in determining the landing location of the CM.

b) Technical Characteristics. The beacon mode shall be one mode of operation of the HF voice subsystem. It shall be compatible with existing HF direction finding equipment. The beacon shall have the transmitting characteristics shown in Table 4.5-4A and utilize an antenna subsystem with characteristics shown in Table 4.5-6.

4.5.4.9 CSM Space-to-Ground Television Subsystem

a) Functional Requirements. The CSM shall have the capability of transmitting television pictures directly to Earth when in line-of-sight of a suitably equipped Earth station.

b) Technical Characteristics. The video data shall be transmitted on the S-band transponder carrier to the Earth. The technical characteristics of this subsystem shall be as shown in Tables 4.5-4B and 4.5-6.

4.5.5 Lunar Excursion Module (LEM) Communications

The communications between the LEM and the Earth shall be provided by S-band equipment. The S-band equipment shall be capable of providing two-way voice, television transmission, data transmission and reception, and tracking. These services shall be obtained by modulation of a common S-band carrier. The communications between the LEM and the CSM shall be provided by VHF equipment.

4.5.5.1 Voice Communication Subsystem. The voice communication subsystem of the LEM shall provide duplex service between the LEM and the Earth, the CSM when separated, and the astronauts. Means shall be provided for the LEM to be used as a relay point for the two-way voice communication between the astronaut exploring the lunar surface and the Earth.

4.5.5.1.1 S-Band Subsystem.

a) Functional Requirements. The S-band subsystem shall provide duplex voice communication between the LEM and the Earth. The S-band subsystem shall have the capability for manually keyed operations with the Earth.

b) Technical Characteristics. The S-band subsystem shall have several modes of operation. These modes differ in the modulation characteristics of the signal and the choice of antenna subsystems. The technical characteristics of the transmitting subsystem shall be as shown in Table 4.5-7, and of the receiving subsystem as shown in Table 4.5-8. The antenna characteristics shall be as shown in Table 4.5-9.

4.5.5.1.2 VHF Subsystem.

a) Functional Requirements. The VHF voice subsystem shall be capable of providing voice communications with: (1) the CSM when the LEM and the CSM are in line-of-sight, and (2) lunar explorers who are in line-of-sight of the LEM and are equipped with the back pack communication subsystem as specified in Section 4.5.6 to distances of at least three nm. This subsystem shall also be capable of relaying voice communication from the CSM to the lunar explorers and from the lunar explorers to the CSM. This subsystem shall be capable of manually keyed operation in an emergency mode. Conference capability between a lunar explorer, an astronaut in the LEM, and the Earth (using the S-band link) shall be provided. The VHF voice subsystem shall also be capable of receiving biomedical data from the back pack communication subsystem specified in Section 4.5.6.

b) Technical Characteristics
(To be included in a later edition.)

4.5.5.1.3 Interior Voice Communications Subsystem

a) Functional Requirements. The interior voice communications subsystem shall provide voice service between crew members within the LEM.

b) Technical Characteristics
(To be included in a later edition.)

4.5.5.2 Telemetry (Space-to-Ground Data) Subsystem

a) Functional Requirements. The LEM shall be provided with an S-band telemetry subsystem to transmit data to the Earth.

b) Technical Characteristics. The technical characteristics for the transmitting subsystem shall be as shown in Table 4.5-7 and for the antenna subsystem as given in Table 4.5-9. The telemetry subsystem shall have the capability of transmitting information to the Earth for verification of the data received by the up-data link subsystem.

4.5.5.3 Up-Data Link (Ground-to-Space Data) Subsystem. The LEM shall incorporate an up-data link subsystem for the reception of data from the Earth. It shall be possible to verify data received at the LEM by transmission of information over the LEM telemetry subsystems to Earth.

4.5.5.4 LEM-to-CSM Data Subsystem

a) Functional Requirements. The LEM-to-CSM data subsystem shall be capable of providing data transmission service from the LEM to the CSM.

b) Technical Characteristics
(To be included in a later edition.)

4.5.5.5 CSM-to-LEM Data Subsystem

a) Functional Requirements. *As a design objective, the CSM-to-LEM data subsystem shall be capable of providing reception at the LEM of data from the CSM.*

b) Technical Characteristics
(To be included in a later edition.)

4.5.5.6 LEM Space-to-Ground Television Subsystem

a) Functional Requirements. The LEM shall incorporate the capability of taking and transmitting television pictures directly to Earth during lunar surface operations, *and, as a design objective during descent and ascent.*

b) Technical Characteristics. The video data shall be transmitted on the S-band transponder carrier to the Earth. Technical characteristics of this subsystem shall be specified in Tables 4.5-7 and 4.5-9.

4.5.5.7 Transponder Subsystem

4.5.5.7.1 Earth-Tracking Transponder

a) Functional Requirements. The LEM shall be provided with an S-band transponder that operates with the deep-space tracking subsystem specified in Section 4.8.6.1.2.1.

b) Technical Characteristics. The S-band signals for earth-tracking of the LEM shall be multiplexed with the voice, data and telemetry services. The antenna characteristics shall be as shown in Table 4.5-9. The technical characteristics of the transmitting subsystem shall be as shown in Table 4.5-7, and of the receiving subsystem as shown in Table 4.5-8.

4.5.5.7.2 CSM-Tracking Transponder

a) Functional Requirements. The LEM shall be equipped with a transponder to permit tracking of the LEM by a radar in the CSM as specified in Section 4.5.4.7.

b) Technical Characteristics.
(To be included in a later edition.)

4.5.5.8 LEM Tracking Subsystem

a) Functional Requirements. The LEM shall be equipped with a radar capable of tracking the CSM provided with a transponder as specified in Section 4.5.4.6.2. The performance characteristics of the LEM radar shall be as shown in Section 4.4.5.3.5.

b) Technical Characteristics
(To be included in a later edition.)

4.5.5.9 LEM Landing Radar

a) Functional Requirements. The LEM shall be equipped with a landing radar with performance characteristics as shown in Section 4.4.5.3.6.

b) Technical Characteristics

(To be included in a later edition.)

4.5.6 Spacesuit/Back Pack Communication Subsystem

a) Functional Requirements. The spacesuit/back pack communication subsystem shall provide the capability for line-of-sight (1) biomedical data transmission to the LEM for distances of at least three nm, (2) duplex voice communication with the LEM for distances of at least three nm, (3) two-way voice communication with the CSM, and (4) two-way voice communication between two astronauts external to the spacecraft for distances of at least [one] nm.

b) Technical Characteristics

(To be included in a later edition.)

[redacted]

Table 4.5-1

Launch Vehicle Transmitting Subsystem Characteristics

Description	S-IC Telemetry	S-II Telemetry	S-IVB Telemetry	IU Telemetry	IU Transponder	IU [Transponder]	IU [Radar Altimeter]
Operating Frequency Band (Mc)	225 - 260	225 - 260	225 - 260	225 - 260	5400-5900		
Modulation Character-istics	PCM/FM Non-return-to-zero (NRZ) PCM bit rate of [72] kbits/sec	PCM/FM Non-return-to-zero (NRZ) PCM bit rate of [72] kbits/sec	PCM/FM Non-return-to zero (NRZ) PCM bit rate of [72] kbits/sec	PCM/FM Non-return-to-zero (NRZ) PCM bit rate of [72] kbits/sec	PULSE		[PULSE]
Minimum Effective Radiated Power* (Watts)							

*Effective Radiated Power - the product of the antenna input power (transmitter output power less transmission line loss) and the antenna power gain at the peak of the main lobe.

[redacted]

Table 4.5-5

Command and Service Module Receiving Subsystem Characteristics

Description	VHF Voice		HF Voice	Up-Data	Transponder	S-Band			
Operating Frequency Band (Mc)	[250-300]		[8-12]	[400-450]	[5400-5900]	[2105-2110]			
Associated transmitter signal characteristics See Section:	DSBAM 4.8.6.4.1, 4.5.6, and 4.5.5.1.2	Keyed Operation 4.5.5.1.2		4.8.6.3.1.	4.8.6.1.1.1	Voice FM/PM 4.8.6.4.2	Up-Data PSK/FM/PM 4.8.6.3.2	Ranging PM 4.8.6.1.2.1	Carrier 4.8.6.1.2.1
Minimum S/N Ratio (db) of:									
as measured at the:									
provided by a minimum usable power density (dbw/m^2) of:									

Table 4.5-5

Command and Service Module
Receiving Subsystem Characteristics

Con

Description	Mode I			Mode II				
Operating Frequency Band (Mc)	[2285 - 2290]			[2285 - 2290]				
Modulation Characteristics	Voice FM/PM	Telemetry PCM/PM/PM	Carrier	Voice FM/PM	Telemetry PCM/PM/PM	Ranging PM	Carrier	Ran I
Baseband Characteristics	___db of peak clipping of the baseband signal for a peak factor of ___db. 3 db baseband frequency response ___ to ___cps.	Serial non-return-to-zero (NRZ) PCM bit rate [51.2]kbits/ sec.	Received Carrier	___db of peak clipping of the baseband signal for a peak factor of ___db. 3db baseband frequency response ___ to ___cps.	Serial non-return-to-zero (NRZ) PCM bit rate [51.2] kbits/ sec.	Determined by ground systems. See Section 4.8.6.1.2	Not Applicable	Deter by g syster See Se 4.8.6.
Sub-carrier	[1.25] Mc	[1.024] Mc	None	[1.25] Mc	[1.024] Mc		None	
Modulation Index (baseband on subcarrier)	[2.50]	[1.57]	None	[2.50]	[1.57]		None	
Modulation Index (subcarrier alone on carrier)	[0.91]	[1.25]	Phase locked with [240/221] frequency ratio to rec. carrier				Phase locked with [240/221] frequency ratio to rec. carrier	
Minimum Effective Radiated Power* (Watts)								

*Effective Radiated Power — the product of the antenna input power (transmitter output power less transmission line loss) an

FOLDOUT FRAME /

Table 4.5-4B

mand and Service Module S-Band Transmitting Subsystem Characteristics

Mode III (Ranging)		Mode IV			Mode V			
[2285 - 2290]		[2285 - 2290]			[2285 - 2290]			
ging PM	Carrier	Voice FM/PM	Telemetry PCM/PM/PM	Carrier	Voice FM/PM	Telemetry PCM/PM/PM	Ranging PM	Car
nined round ns ction: 1.2	Not Applicable	___db of peak clipping of the baseband signal for a peak factor of ___db. 3db baseband frequency response ___ to ___cps.	Serial non-return-to-zero (NRZ) PCM bit rate [1.6] kbits/sec.	Not Applicable	___db of peak clipping of the baseband signal for a peak factor of ___db. 3db baseband frequency response ___ to ___cps.	Serial non-return-to-zero (NRZ) PCM bit rate [1.6] kbits/sec.	Determined by ground systems. See Section: 4.8.6.1.2	N Appli
	None	[1.25] Mc	[1.024] Mc	None	[1.25] Mc	[1.024] Mc		Nc
	None	[2.50]	[1.57]	None	[2.50]	[1.57]		N
	Phase locked with [240/221] frequency ratio to received carrier	[.91]	[1.25]	Phase locked with[240/221] frequency ratio to received carrier				Phase with [2 ratio tc ceived

l the antenna power gain at the peak of the main lobe.

FOLDOUT FRAME 2

	Mode VI (Tape Playback)			Mode VII (Emergency Voice)	Mode VIII (Keyed Operation)		Mode IX (Television)
	[2285 - 2290]			[2285 - 2290]	[2285 - 2290]		[2280 - 2290]
rier	Voice FM/FM	Telemetry PCM/PM/FM	Analog Tape Playback Channels FM/FM	Voice FM	Key	Carrier	
ot cable	___db of peak clipping of the baseband signal for a peak factor of ___db. 3db baseband frequency response ___ to ___cps.	Serial non-return-to-zero (NRZ) PCM bit rate [51.2] kbits/ sec.		___db of peak clipping of the baseband signal for a peak factor of ___db. 3db baseband frequency response ___ to ___cps.	Key	Not Applicable	
ne	[1.25] Mc	[1.024] Mc		None		None	
one	[2.50]	[1.57]		Not Applicable		None	
locked 40/221] re- carrier				[1.00]			

Table 4.5-4B

Command and Service Module S-Band Transmitting Subsystem Characteristics

FOLDOUT FRAME 3

Table 4.5-2

Launch Vehicle Receiving Subsystem Characteristics

Description	S-IC Command-Destruct	S-II Command-Destruct	S-IVB Command-Destruct	IU Up-Data	IU Transponder	IU [Radar Altimeter]	IU [Transponder]
Operating Frequency Band (Mc)	400 - 450	400 - 450	400 - 450	[400 - 450]	5400 - 5900		
Associated transmitter signal characteristics See Section:	4.7.7 and 4.8.6.8	4.7.7 and 4.8.6.8	4.7.7 and 4.8.6.8	4.8.6.3.1	4.8.6.1.1.1	4.5.3.5	
Minimum S/N ratio (db) of:							
as measured at the:							
provided by a minimum usable power density (dbw/m^2) of:							

Table 4.5-2

Launch Vehicle Receiving Subsystem Characteristics

Table 4.5-3

Launch Vehicle Antenna Subsystem Characteristics

Operating Frequency Band (Mc)	225 - 260	400 - 450	225 - 260	400-450	225 - 260	400 - 450	225 - 260	[400 - 450]	5400 - 5900		
Minimum Effective Antenna Gain* (db) over look angles from ___° to ___°			-								
Associated Transmitting and Receiving Subsystems	S-IC Telemetry Transmitter(s)	S-IC Command-Destruct Receivers	S-II Telemetry Transmitter(s)	S-II Command-Destruct Receivers	S-IVB Telemetry Transmitter(s)	S-IVB Command-Destruct Receivers	IU Telemetry Transmitter(s)	IU Up-Data Link Receiver	IU Transponder Transmitter and Receiver	[IU Transponder Transmitter and Receiver]	[IU Radar Altimeter]

*Averaged over a solid angle of ___ steradians.

Table 4.5-3

Launch Vehicle Antenna Subsystem Characteristics

Table 4.5-4A

Command and Service Module Transmitting Subsystem Characteristics

Description	VHF Voice		HF Voice				VHF Telemetry		VHF Recovery Beacon	Radar Transponder
Operating Frequency Band (Mc)	[250 - 300]		[8 - 12]				225 - 260		243	[5400 - 5900]
Modulation Characteristics	DSBAM ____ percent modulation, nominal. ____ db of peak clipping of the baseband signal for a peak factor of ____ db. 3db baseband frequency response ____ to ____ cps.	Keyed Operation	SSBAM ____ percent modulation, nominal ____ db of peak clipping of the baseband signal for a peak factor of ____ db. 3db baseband frequency response ____ to ____ cps.	SSBAM with Suppressed Carrier ____ db of peak clipping of the baseband signal for a peak factor of ____ db. 3db baseband frequency response ____ to ____ cps.	Keyed Operation	Beacon- Interrupted Continuous Wave Transmitter Cycle: on for 2 seconds, off for 3 seconds, repeat.	PCM/FM Serial non-return-to-zero (NRZ) PCM bit rate [51.2] kbits/sec.	PCM/FM Serial non-return-to-zero (NRZ) PCM bit rate [1.6] kbits/sec.		Pulse
Minimum Effective Radiated Power* (Watts)										

*Effective Radiated Power - the product of the antenna input power (transmitter output power less transmission line loss) and the antenna power gain at the peak of the main lobe.

Table 4.5-4A

Command and Service Module Transmitting Subsystem Characteristics

Table 4.5-6

Command and Service Module Antenna Subsystem Characteristics

Description	Omni-Directional VHF/UHF	Normal Recovery VHF/HF	Back Up Recovery VHF/HF	S-Band Directional Manual or Earth Sensing Automatic	S-Band Omni-Directional	Radar Omni-Directional
Operating Frequency Band (Mc)	[225-300] and [400-450]	[225-300] and [8-12]	[225-300] and [8-12]	[2105-2110] and [2285-2290]	[2105 - 2110] and [2285 - 2290]	[5400 - 5900]
Minimum Effective Antenna Gain* (db) over look angles from ___° to ___°.	*	*	*	[Manually selectable, 28 db, 20 db or 12 db]	*	
Associated Transmitting Subsystems	VHF Voice VHF Telemetry VHF Recovery Beacon	VHF Voice HF Voice or Recovery Beacon VHF Recovery Beacon	VHF Voice HF Voice or Recovery Beacon VHF Recovery Beacon	S-Band Transmitting Subsystems	S-Band Transmitting Subsystems	Radar Transponder
Associated Receiving Subsystems	VHF Voice UHF Up-Data	VHF Voice HF Voice	VHF Voice HF Voice	S-Band Receiving Subsystems	S-Band Receiving Subsystems	Radar Transponder

*Averaged over a solid angle of _____ steradians.

Table 4.5-7

LEM Transmitting Subsystem Characteristics

Description	S-Band					
	Primary Voice	Secondary Voice	Primary Telemetry	Secondary Telemetry	Television	Tracking
Operating Frequency Band (Mc)	[2280 - 2285]	[2280 - 2285]	[2280 - 2285]	[2280 - 2285]	[2280 - 2290]	[2280 - 2285]
Modulation Characteristics						
Minimum Effective Radiated Power* (Watts)						

*Effective Radiated Power — the product of the antenna input power (transmitter output power less transmission line loss) and the antenna power gain at the peak of the main lobe.

Table 4.5-8

LEM Receiving Subsystem Characteristics

Description	S-Band			
	Primary Voice	Secondary Voice	Tracking	Up-Data
Operating Frequency Band (Mc)	[2100 - 2105]	[2100 - 2105]	[2100 - 2105]	[2100 - 2105]
Associated Transmitter Signal Characteristics See Section:	4.8.6.4.2	4.8.6.4.2	4.8.6.1.2.1	4.8.6.3.2
Minimum S/N ratio (db) of:				
as measured at the:				
provided by a minimum usable power density (dbw/m^2) of:				

Table 4.5-9

Lunar Excursion Module Antenna Subsystem Characteristics

Description	S-Band Directional (Steerable)	S-Band Omni-Directional	Erectable* S-Band High Gain Directional	VHF Omni-Directional	VHF Directional (Steerable)
Operating Frequency Band (Mc)	[2100-2105] and [2280-2290]	[2100-2105] and [2280-2285]	[2100-2105] and [2280-2290]	[250-300]	[250-300]
Minimum Effective Antenna Gain** (db) over look angles from ___° to ___°		**		**	
Associated Transmitting Subsystems	Voice Telemetry [Television] Tracking	Voice Telemetry Tracking	Voice Telemetry Television Tracking	Voice	Voice
Associated Receiving Subsystems	Voice Tracking Up-Data	Voice Tracking Up-Data	Voice Tracking Up-Data	Voice Back Pack Data	Voice

*To be erected on the lunar surface.
**Averaged over a solid angle of ___ steradians.

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4.6 Checkout.

4.6.1 Scope.

This section specifies requirements on systems to be used for checkout of a) the space vehicle from assembly through mission completion, and b) the ground network used prior to and during the mission.

4.6.2 Purpose of Checkout.

The checkout system shall be capable of operation throughout the Apollo mission for the purpose of assuring crew safety and increasing the probability of mission success. The checkout system shall provide information to assist in assessing the capability of the space vehicle to a) initiate and continue a normal mission, b) initiate and continue a modified mission, or c) perform an aborted mission.

Specific objectives of checkout shall include the following:

a) to provide assurance of readiness of the space vehicle and earth-based systems before earth launch of the space vehicle;

b) to provide assurance of readiness of the system for initiation of each mission phase from insertion into earth parking orbit until mission completion;

c) to provide diagnostic assistance for fault isolation and possible correction;

d) to perform evaluation of critical systems;

e) to evaluate trends; and

f) to provide research and development information.

4.6.3 Checkout of Space Vehicle Systems.

4.6.3.1 General Design Requirements. The Apollo space vehicle and ground system shall be designed to be compatible with an integrated checkout concept covering pre-launch, launch, in-flight and lunar operation phases of the mission.

The system shall incorporate provisions for monitoring and analyses of critical system functions in such a manner that out-of-tolerance performance can be recognized and assessed, both on the ground and by the flight crew using on-board equipment, in time for remedial action.

No equipment used solely for pre-launch testing shall be installed aboard the spacecraft as fly-away hardware unless an overall program saving can be demonstrated.

Test equipment installed aboard the space vehicle as fly-away hardware shall be compatible with all equipment used in the several phases of checkout.

Checkout facilities aboard the spacecraft may be a combination of manual and automated systems. From insertion into earth parking orbit through mission completion, this equipment shall provide information on spacecraft systems to allow independent on-board go/no-go decisions.

The spacecraft telemetry system shall be provided with at least as much checkout data as is available to the on-board crew.

IMCC, when furnished with the flight checkout data from the spacecraft, shall be capable of generating go/no-go information.

Where applicable, earth-based facilities shall be capable of comparing in-flight data and pre-flight tests data to reveal trends and to develop confidence in the on-board equipment.

Earth-based checkout facilities shall be designed to provide a maximum flexibility so that a minimum of modification will be required to support missions beyond the initial manned lunar landing. These facilities shall be automated wherever practicable.

4.6.3.2 Location of Checkout Functions.

4.6.3.2.1 Pre-launch. Pre-launch checkout of the space vehicle shall be performed at the Merritt Island Launch Area (MILA). Checkout facilities shall be compatible with the operating concepts delineated in the latest issue of the directive entitled "Basic Operating Concepts for the Launch Operations Center at the Atlantic Missile Range." The capability for transmitting checkout information from MILA to IMCC shall be provided.

4.6.3.2.2 Post-launch. IMCC shall have the capability of assessing CM, SM, and LEM checkout data from earth launch through completion of the mission. LOC shall have the capability of performing checkout of the S-IVB/IU in earth parking orbit by receiving checkout data via IMCC and by requesting IMCC to initiate checkout commands. IMCC shall also have the capability of performing checkout of the S-IVB/IU in earth parking orbit.

4.6.3.3 Time of Checkout. Checkout of space vehicle systems shall be performed at specified times prior to launch. Certain critical systems shall then be continually assessed. After insertion into earth parking orbit, specific checkouts shall be performed prior to each major propulsion event. Should any appreciable delays occur, appropriate portions of the checkout shall be repeated.

As a design objective, the capability shall be provided to perform checkout of the space vehicle (consisting of the CM, SM, LEM, S-IVB, and IU) during the first earth parking orbit. As a minimum capability, the system shall be capable of performing this checkout during the first two orbits.

In addition to the checkouts associated with major propulsion events, checkouts shall be made at other times. These shall include:

a) checkout of the CM, SM, and LEM after repositioning of the LEM on the CM in lunar transfer trajectory;

b) checkout of the LEM after landing on the lunar surface and before deployment of an astronaut for exploration; and

c) checkout of the CM before re-entry into Earth's atmosphere.

4.6.4 Checkout of Earth-Based Systems

4.6.4.1 General Design Requirements.

(To be included in a later edition.)

4.6.4.2 Location of Checkout Functions. The IMCC shall have the capability of initiating and controlling the checkout of the ground communication network. The IMCC shall have the capability of advising various elements of the system, as appropriate, of the results of all checkouts.

4.6.4.3 Time of Checkout.

(To be included in a later edition.)

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4.7 Launch Area

4.7.1 Scope

This section specifies the capability requirements of equipment and facilities located at Merritt Island Launch Area (MILA) which are used in the conduct of manned lunar-landing mission operations commencing with Apollo space vehicle assembly and terminating with post-mission evaluation. These facilities shall include:

a) Launch Complex 39 - at which the launch vehicle stages are prepared and the space vehicle is assembled and launched.

b) Spacecraft Operations and Checkout Facilities - where spacecraft modules are assembled and readied for mating with the launch vehicle and from which the spacecraft operations and checkout will be conducted during the pre-launch and launch phases.

c) Support Facilities - such as communications, tracking and data facilities which are used within the launch area and for external communications to Range and other ground facilities and to the space vehicle.

4.7.2 Objectives

The equipment and facilities shall support the Apollo mission by:

a) performing vertical assembly, alignment, interface and systems compatibility verification; routine maintenance, modification, parts replacement and repairs; checkout, countdown and launch of the Apollo space vehicle;

b) obtaining and providing space vehicle and astronaut status data during the pre-launch and launch phases;

c) obtaining and providing tracking and telemetry data during contact with the space vehicle in the launch and earth orbit phases of the mission;

d) providing for safety during pre-launch and launch operations;

e) assisting IMCC in the conduct of in-flight checkouts of the space vehicle and of the astronauts.

4.7.3 General Design Requirements

The launch area equipment and facilities shall be compatible with the checkout concept as specified in Section 4.6 for the pre-launch, launch, in-flight, and lunar operational phases.

Existing launch area equipment and facilities shall be used, wherever feasible, to satisfy the preparation, launch and mission support requirements of the Apollo program.

As a design objective, the launch area equipment and facilities shall not constrain the ability of the Apollo space vehicle to meet launch windows.

4.7.4 Launch Rate Capability Requirements

As a minimum capability, the launch area equipment and facilities shall be capable of satisfying the Apollo launch requirements specified in OMSF Program Directive M-DE 8000.005*.

The equipment and facilities shall be capable of launching two Apollo space vehicles from Launch Complex 39 within an interval of [2 weeks].

4.7.5 Launch Complex 39 Requirements

4.7.5.1 General. Launch Complex 39 shall be constructed in accordance with a "mobile concept" of launch operations embodying the basic principle of vertical assembly and checkout of the space vehicle in a suitably equipped building and transfer of the space vehicle in an erect position to the launch pad.

The equipment and facilities of Complex 39 shall include:

a) Launch Control Center (LCC) - the launch area focal point from which launch area operations shall be coordinated during the pre-launch, launch, and in-flight phases.

b) Vertical Assembly Building (VAB) - the central facility in which launch vehicle stages shall be prepared and assembled, the space vehicle assembled, and initial overall space vehicle checkout conducted.

*OMSF Program Directive M-DE 8000.005A - Apollo Flight Mission Assignments Document. Issue dated April, 1963.

c) Launcher Umbilical Tower (LUT) - the transportable launching platform and integral umbilical tower on which the space vehicle shall be assembled, transported and launched.

d) Arming Tower - the transportable structure which shall provide access to the space vehicle at the launch pad for servicing system components and installing major ordnance items.

e) Crawler-Transporter - the prime mover for the LUT/Space Vehicle and for the Arming Tower.

f) Launch Pad Area - the site, equipment and facilities used for the final servicing (including propellant loading), and for launch of the space vehicle.

4.7.5.2 Scheduling Requirements. The equipment and facilities of Complex 39 shall be designed such that normal launch operations on the Apollo space vehicle can be conducted within the limits of the following schedule:

a) VAB High Bay - launch vehicle assembly, preparation and checkout. [6 weeks]

b) VAB High Bay - space vehicle assembly, preparation and checkout. [3 weeks]

c) Pad Time - including transfer of LUT/Space Vehicle from the VAB. [3 weeks]

d) Pad refurbishing time. [1 week]

e) LUT/Space Vehicle return from pad to VAB from any degree of readiness. [24 hours]

As a design objective, pad time shall be limited to one week. If this design objective is achieved, the requirement of item (b) may be modified.

4.7.5.3 Launch Control Center (LCC). Commencing with initial vehicle preparation in the high bay areas, the LCC shall be capable of providing central control and coordination of launch area activities involved in the pre-launch and in-flight mission support of the space vehicle. The LCC shall be equipped to:

a) supervise the preparation and conduct pre-launch checkout of the space vehicle;

b) conduct the countdown and launch of the space vehicle;

c) support the earth orbit checkout of the S-IVB/IU as specified in Section 4.6;

d) participate in and conduct simulated countdown, launch and flight operations;

e) coordinate launch operations with the requirements imposed by the range agency;

f) display the status of the astronauts, the space vehicle and the launch area facilities.

4.7.5.4 Vertical Assembly Building (VAB). The VAB shall provide an enclosed area and facilities for the final assembly and pre-launch preparation of launch vehicle stages and systems in a protected and, where required, controlled environment.

The VAB shall also provide an enclosed high bay area and facilities for the vertical assembly and system operation verification and checkout of the complete Apollo space vehicle aboard the LUT. It shall provide access and equipment to complement that of the LUT for calibration, checkout, and RF verification of the vehicle prior to its transfer to the launch pad.

The VAB shall contain adequate facilities and equipment for emergency and limited medical treatment of personnel working in the VAB, LUT and the Launch Pad Area.

The VAB shall be designed to withstand winds up to 125 MPH. Its design and location shall be such that normal operations at a launch pad shall not restrict VAB operations.

4.7.5.5 Launcher-Umbilical Tower (LUT). The transportable LUT shall provide support and holddown of the space vehicle for all operations from vehicle assembly to liftoff. The LUT shall provide:

a) umbilical service arms connecting the space vehicle to the umbilical tower and the ground support equipment;

b) access to the umbilical connection areas of the vehicle;

c) a CM access arm with a controlled environment area;

d) a means for astronaut rapid egress from the CM;

e) equipment areas providing protection from vibration, noise and other conditions incurred during launch;

f) connection points into the launch pad facilities including those for electrical power, propellant systems, water quench systems and communications;

g) lightning protection and a grounding system for the space vehicle.

While secured at the launch pad or at its parking/refurbishing area without a space vehicle aboard, the LUT shall be capable of withstanding winds up to 125 MPH.

While secured at the launch pad with a space vehicle aboard, the LUT shall be capable of withstanding wind conditions given by the 99.9% probability of occurrence table in OMSF Program Directive M-DE 8020.008*.

4.7.5.6 Arming Tower. The Arming Tower shall provide facilities and access to the space vehicle for the installation of major ordnance and related equipment, and shall provide access to the space vehicle for servicing system components.

The Arming Tower shall be capable of being transported to and from the launch pad by the Crawler-Transporter. While secured either at the launch pad, or at its parking/refurbishing area, the Arming Tower shall be capable of withstanding winds up to 125 MPH.

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*OMSF Program Directive M-DE 8020.008A - Natural Environment and Physical Standards for Project Apollo. Issue dated August, 1963.

4.7.5.7 Crawler-Transporter. The Crawler-Transporter shall be capable of:

a) lifting and transporting the LUT/Space Vehicle (unfueled) or the Arming Tower in 99% probable ground winds during the strongest wind month. The load imposed on the unfueled space vehicle during transportation by the combined effects of wind and Crawler-Transporter motion shall not exceed the design strength of the vehicle.

b) supporting the LUT/Space Vehicle in 99.9% probable ground winds during the strongest wind month while stopped enroute between the VAB and the launch pad.

c) moving at the rate of 1 MPH loaded and 2 MPH unloaded. It shall be capable of carrying a load up to 12,000,000 pounds. The Crawler-Transporter leveling system shall be designed to maintain the LUT chassis within [5] minutes of level at all times, with the further requirement that no point in the support plane shall be out of plane more than [2] inches at any time.

d) providing power requirements and electrical grounding for the LUT/Space Vehicle and Arming Tower during transport.

All launch area reference design wind speeds shall be as specified in OMSF Program Directive M-DE 8020.008*.

4.7.5.8 Launch Pad Areas. The Launch Pad Areas shall be designed to accomplish final preparation of the space vehicle for launching; including propellant and ordnance loading, final checkout, countdown, and launch.

The Launch Pad Areas shall be designed and located to permit concurrent countdowns on adjacent pads. The Launch Pad Area shall be designed to permit around-the-clock usage.

The pad area shall provide all access, servicing facilities, and support capability required to perform pre-launch operations required at the pad.

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* OMSF Program Directive M-DE 8020.008A - Natural Environment and Physical Standards for Project Apollo. Issue dated August, 1963.

The Launch Pad Area equipment and facilities shall be capable of maintaining all space vehicle systems in a standby condition such that they are capable of successful operation after a vehicle standby time of up to [12 hours]. Standby time, as used above, is defined as the period after all propellants are loaded until vehicle lift-off.

4.7.5.8.1 Launch Pad. The coordinates of the launch pads shall be as specified in OMSF Program Directive M-DE 8020.008*, with the on-pad vehicle positive pitch axis aligned in a true south direction.

Piers and jacks for the support and tie-down of the LUT/ Space Vehicle shall be oriented such that the umbilical tower is north (true) of the vehicle. The Arming Tower support piers shall be positioned south of the vehicle.

4.7.5.8.2 Cryogenics. Cryogenic propellant transfer systems shall be capable of completing launch vehicle chilldown and loading operations in [2.5 hours] or less. Cryogenic unloading and flush time shall not exceed [3 hours].

Cryogenic replenish systems shall be capable of maintaining vehicle propellant levels for a minimum of [12 hours] after final cryogenic loading.

4.7.5.8.3 RP-1. The RP-1 storage and transfer system shall be capable of loading or unloading the S-IC stage in [2 hours] or less.

4.7.5.8.4 Hypergolics Facilities. The hypergolic transfer systems shall be capable of loading or unloading the S-IVB hypergolic propellants in ______ minutes or less and the spacecraft hypergolic propellants in ______ hours or less.

4.7.5.8.5 High Pressure Gases. High Pressure Gas facilities shall have sufficient capacity to accommodate vehicle loading requirements, pad and vehicle accessory operation, and repetitive purging requirements.

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*OMSF Program Directive M-DE 8020.008A - Natural Environment and Physical Standards for Project Apollo. Issue dated August, 1963.

4.7.6 Launch Area Support Facilities.

4.7.6.1 Operations and Checkout Facilities (O & C). The O & C Facilities shall be capable of supporting checkout, maintenance and repair of the spacecraft and flight crew equipment during operations in the VAB and on the launch pad.

The O & C Facilities shall be capable of sustaining, examining, and providing medical care for flight crews prior to mission simulations and launches and shall provide for the transport of the flight crew in flight-ready condition to the launch pad.

4.7.6.2 Central Instrumentation Facility (CIF). (To be presented in a later issue)

4.7.6.3 Atlantic Missile Range. As an operational component of the Air Force Systems Command, the Air Force Missile Test Center develops, maintains, and operates the AMR. Under this mission, AFMTC is responsible for obtaining and coordinating all government and contractor services needed at AMR to provide equitable support for the DOD, NASA, and other agency programs consistent with established national policies and priorities. Range support shall be in accordance with the provisions of the NASA/DOD Agreement of 17 January 1963, entitled "Agreement between The Department of Defense and The National Aeronautics Space Administration Regarding Management of the Atlantic Missile Range of DOD and the Merritt Island Launch Area of NASA."

4.7.7 Launch Area Communications, Tracking and Data Facilities. (To be presented in a later issue.)

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4.8 Ground Communication and Tracking System (GCTS)

4.8.1 Scope

This section contains the system specifications for the elements of the Ground Communication and Tracking System (GCTS). The GCTS is defined, in this specification, as the complex of ground stations deployed around the world for tracking and communicating with the space vehicle, and the communication network interconnecting IMCC, MILA, RCC, and these ground stations. Tracking computations shall be performed by the real time computer complex (RTCC) located at the IMCC. The specifications for the RTCC are given in Section 4.9. Similarly, the communication function requires communication facilities which will also be located at IMCC and are specified in Section 4.9.

4.8.2 Objectives

The GCTS shall include facilities for:

a) obtaining data for use in determining the space vehicle position and trajectory parameters;

b) receiving and processing data telemetered from the space vehicle to Earth;

c) transmitting data from the Earth to the space vehicle;

d) establishing two-way voice communication between the Earth and the spacecraft;

e) receiving television signals from the LEM and the CSM;

f) obtaining pointing angle and space vehicle frequency data to facilitate acquisition of the space vehicle signal by the steerable antennas;

g) communication between all Apollo sites and the IMCC;

h) voice communications between operating positions at each site and between the positions and the intersite communication network;

i) synchronizing time between sites, and between sites and spacecraft;

j) conducting simulation and training operations;

k) recording all pertinent data; and

l) maintaining a satisfactory level of performance.

4.8.3 Design Guidelines

The GCTS shall, wherever practicable, be designed for automatic operation under human control and shall provide easy voice contact with the spacecraft crew.

Existing sites and equipments shall be used, where feasible.

4.8.4 GCTS Sites

4.8.4.1 Classes of Sites. The GCTS sites may be divided into two general classes: near-earth and deep-space sites.

The near-earth sites shall be able to perform the following functions:

a) launch coverage including tracking of, two-way voice communication with, telemetry reception from, and transmission of data to the space vehicle during the launch phase;

b) Earth orbit coverage, including tracking of, two-way voice communication with, telemetry reception from, and data transmission to the space vehicle;

c) coverage, as specified below, of second ignition of S-IVB and coast in lunar transfer trajectory until the deep-space sites can acquire the space vehicle; and

d) re-entry coverage including tracking of and communicating with the spacecraft.

The deep-space sites shall be capable of providing two-way voice communication with, tracking of, telemetry and television reception from, and data transmission to the spacecraft during the deep-space phases of the mission and, where feasible, during other phases.

4.8.4.2 Coverage. GCTS sites shall be located to provide tracking and communication coverage as specified below for the trajectories given in Section 3.3. The accuracy of the geodetic location (referenced to the Fischer ellipsoid of 1960) of the land-based tracking stations and ship tracking stations shall be determined to within the following limits:

	Land-based Stations	Ship Stations
Latitude	$\pm$ ______ ft.	$\pm$ ____ nm
Longitude	$\pm$ ______ ft.	$\pm$ ____ nm
Altitude	$\pm$ ______ ft.	$\pm$ ____ ft.
Deflection of the Vertical	$\pm$ ______ mr.	$\pm$ ____ mr.
Deflection of True North	$\pm$ ______ mr.	$\pm$ ____ mr.

The accuracy of the location of the air-borne communication stations shall be determined to within the following limits:

	Air-borne Stations
Latitude	$\pm$ ________ nm
Longitude	$\pm$ ________ nm
Altitude	$\pm$ ________ ft.

4.8.4.2.1 Near-Earth Sites. The near-earth sites shall have the following coverage capability:

a) tracking, voice, telemetry, and up-data communications coverage from lift-off through insertion into Earth parking orbit (end of S-IVB first burn) and for [five] minutes thereafter. There shall be no coverage gap greater than [zero] minutes during this interval; and

b) tracking, voice, telemetry, and up-data communications coverage during the Earth parking orbit(s) shall be as follows:

ORBIT	Tracking		Voice and Telemetry		Up-Data	
	Minimum Coverage	Maximum Gap	Minimum Coverage	Maximum Gap	Minimum Coverage	Maximum Gap
1	(Minutes)	(Minutes)	(Minutes)	(Minutes)	(Minutes)	(Minutes)
2						
3						
4						

c) telemetry and voice (reception only) coverage for an interval extending from __________ minutes prior to the start of S-IVB second burn through the end of S-IVB second burn with no coverage gap greater than [zero] minutes. Continuous tracking of the space vehicle shall be possible for a period of _________ minutes within _________ minutes of the end of the second burn of the S-IVB;

d) voice, telemetry and up-data communications coverage from injection until acquisition by the deep-space sites, with no gap in voice and telemetry communication in excess of ____________ minutes and no gap in up-data transmission in excess of __________ minutes. The near-earth sites shall be capable of providing continuous voice, telemetry and up-data communications from [one] minute prior to separation until __________ minutes after repositioning.

As a design objective, it shall be possible to track the S-IVB/IU from suitably equipped ground stations within _____ minutes of jettison for a period of ______ minutes with no gap greater than ________ minutes;

e) coverage during re-entry, between the altitudes of __________ and __________ nautical miles with no gap in telemetry and voice communication coverage in excess of __________ minutes, no gap in tracking coverage in excess of __________ minutes, and no gap in up-data transmission coverage in excess of __________ minutes.

4.8.4.2.2 Deep-Space Sites. The deep-space sites shall permit:

a) communications with and tracking of the CSM and LEM during all powered flight maneuvers performed in deep-space (except when such maneuvers are obscured by the Moon) and for __________ minutes thereafter with no gap greater than __________ minutes.

b) communications with and tracking of the CSM and LEM for at least __________ hours per day with no gap greater than __________ hours, when the CSM and LEM are at an altitude in excess of __________ nautical miles from the Earth, except when they are obscured by the Moon.

4.8.5 GCTS Instrumentation

4.8.5.1 Subsystems. The GCTS sites shall be equipped with certain of the following subsystems:

a) tracking;
b) telemetry (space-to-ground data);
c) up-data link (ground-to-space data);
d) two-way space-ground voice;
e) television receiving;
f) intra-site communication;
g) timing;
h) inter-site communication;
i) recording; and
j) data processing.

4.8.5.2 Interference. In planning, developing and operating the GCTS, the effects of r-f interference shall be carefully considered and controlled. Some of the requirements to obtain this control are:

a) The level of r-f interference from non-Apollo sources shall be determined. Facilities shall be provided as necessary to monitor the frequency bands which could cause interference with Apollo tracking and communications;

b) Interference between Apollo equipments shall not result in impairment of system performance; and

c) The IMCC shall be provided with facilities to permit control and coordination of transmission periods of individual sites to reduce mutual interference between ground-space links.

4.8.5.3 Recording. Facilities shall be provided to allow recording of information (voice, telemetry, television, data) passing between the space vehicle and the Earth, information flowing between sites, tracking data and performance parameters of certain site subsystems.

4.8.5.4 Data Processing. Certain GCTS sites shall be capable of on-site data processing involving logical operations to compress and/or smooth digital data inputs and perform "in-or-out of limit" data analysis. Data conditioning functions (as specified in later portions of this section), which are not available in the prime equipment, shall be provided by the data processing equipment.

4.8.6 Subsystem Specifications

4.8.6.1 Tracking Subsystem

4.8.6.1.1 Near-Earth Tracking Subsystem. The tracking subsystem at near-earth tracking stations shall include the following major equipment elements:

a) radar;
b) data conditioning;
c) data monitoring;

d) acquisition; and

e) [optical trackers].

4.8.6.1.1.1 Radar. The radars shall have the capability of tracking the space vehicle transponders (specified in Section 4.5) during the near-earth phases of the mission until acquisition by the deep-space sites.

The technical characteristics of the tracking subsystem shall be as given in Table 4.8-1.

4.8.6.1.1.2 Data Conditioning. The data conditioning equipment shall be capable of accepting data samples from the radar and converting them to coded digital form for transmission to the RTCC. The data conditioning equipment shall permit the sampling of the radar storage registers at a rate consistent with the capacity of the outgoing transmission facilities. At stations equipped for high-speed data (voice bandwidth) transmission, the maximum and minimum sampling rates shall be __________ and __________ times per second, respectively; at stations equipped for teletypewriter speed transmission, the maximum and minimum sampling rates shall be once every __________ seconds and ____________ seconds, respectively.

Each message frame shall include data which permits the derivation of the azimuth, elevation, range, time, station identification, and an indication of the quality of the tracking data (i.e., whether valid or not). Frames originated by tracking ship stations shall also include ship position and stability conditions.

4.8.6.1.1.3 Data Monitoring. Displays shall be provided for establishing the validity of the tracking data transmitted to the RTCC. Those stations equipped for data processing shall be provided additional displays to permit monitoring of processed data.

4.8.6.1.1.4 Acquisition. The acquisition subsystem at each near-earth site shall include equipment capable of automatic angle tracking of the VHF telemetry signal radiated by the space vehicle, and an acquisition data distribution subsystem which permits the synchronization of all steerable antennas at a site.

The acquisition angle tracking equipment shall be capable of being pointed:

a) manually;

b) automatically, using telemetry signals from the space vehicle; and

c) from data supplied by the acquisition data distribution subsystem.

The technical characteristics of the automatic angle tracking equipment shall be as given in Table 4.8-1.

Displays indicating the performance and mode of all tracking systems shall be provided to permit selection of the best source of pointing data for the acquisition data distribution subsystem.

4.8.6.1.2 Deep-Space Tracking Subsystem. The tracking subsystem at deep-space tracking stations shall include the following equipment elements:

a) S-band tracking subsystem;
b) data conditioning;
c) data monitoring; and
d) acquisition.

4.8.6.1.2.1 S-Band Tracking Subsystem. The S-band tracking subsystem shall be capable of tracking the spacecraft within the coverage volume specified in Section 4.8.4.2.2.

This subsystem shall have the capability of measuring range, range-rate and angular position of the location of the spacecraft. It shall provide phase-coherent reception and shall operate in conjunction with S-band transponders (specified in Section 4.5) which are carried by the CSM and LEM. Communication services as specified in Sections 4.8.6.2.2, 4.8.6.3.2, 4.8.6.4.2, and 4.8.6.5 shall be multiplexed with the S-band tracking signals and shall use the same antennas and r-f transmitting and receiving equipment. The subsystem shall be capable of simultaneous tracking of both the CSM and the separated LEM from the time the spacecraft separate until rendezvous, except when they are obscured by the Moon.

It shall be possible to use some of the equipments at certain of the Deep Space Instrumentation Facility (DSIF) sites used for communication with and tracking of unmanned space probes, for back-up support of the Apollo deep space sites.

The S-band tracking subsystem shall have the technical characteristics shown in Table 4.8-2.

4.8.6.1.2.2 Data Conditioning. Equipment shall be provided with the capability for accepting data samples from the S-band tracking subsystem and converting them to coded digital form for transmission to the RTCC at a rate consistent with the capacity of the outgoing transmission facilities. At stations equipped with high-speed data transmission facilities, the maximum and minimum sampling rate shall be ____________ and ____________ times per second, respectively; at stations equipped for teletypewriter speed transmission, the maximum and minimum sampling rates shall be ____________ and ____________ times per second, respectively.

Each message frame shall include data which permits the derivation of the azimuth, elevation, range, range-rate, time, station identification, and an indication of the quality of the tracking data (i.e., whether valid or not).

4.8.6.1.2.3 Data Monitoring. Displays shall be provided to permit a determination of the validity of tracking data transmitted to the RTCC. Those stations equipped for data processing shall be provided additional displays to permit monitoring of the processed data.

4.8.6.1.2.4 Acquisition. The acquisition subsystem at each deep-space site shall provide data to the S-band tracking subsystem for use in acquiring the spacecraft. The acquisition subsystem shall be compatible with the S-band tracking subsystem and the spacecraft subsystem specified in Sections 4.8.6.1.2.1 and 4.5 respectively and shall be capable of acquiring the spacecraft at a range of at least __________ nm. When there is more than one S-band tracking subsystem at a site, all of the steerable antennas shall be synchronized and controlled by either the acquisition subsystem or inputs derived from one of the tracking antennas. In addition, acquisition shall be possible using manually inserted data.

Displays of the performance and mode of all tracking subsystems shall be provided for selection of the best available pointing data.

The acquisition subsystem shall have the technical characteristics shown in Table 4.8-2.

4.8.6.2 Telemetry (Space-to-Ground Data) Subsystem. Certain GCTS sites shall be equipped to receive telemetry data from the space vehicle. These sites shall be able to:

a) record incoming data;

b) identify individual blocks of data and appropriately route the data using automatic equipment; and

c) monitor the flow of data to determine its validity.

4.8.6.2.1 Near-Earth Telemetry Subsystem. The near-earth sites shall be capable of receiving data telemetered from the space vehicle as follows:

Mission Phase	Telemetry Data from
Launch	S-IC, S-II, S-IVB, IU, CSM, LEM
Earth Orbit and Injection	S-IVB, IU, CSM, LEM
Re-entry	CM

The telemetry receiving and antenna subsystems shall have the technical characteristics given in Table 4.8-3. Demodulation and decommutation techniques, individual channel assignment, and channel characteristics of each telemetry receiving subsystem shall be compatible with its respective source specified in Section 4.5.

4.8.6.2.2 Deep-Space Telemetry Subsystem. A subsystem for receiving telemetry data from the CSM and the LEM shall be provided at the deep-space stations. The subsystem shall be capable of simultaneously recovering telemetry data which has been multiplexed on carriers of the CSM and LEM transponders.

The technical characteristics of the telemetry subsystem shall be as given in Table 4.8-4.

4.8.6.2.3 Data Conditioning. The data conditioning equipment for telemetered data shall permit conditioning in different ways, depending on the phase of the mission, the resulting character of the data being received from the spacecraft, and the facilities available for transmission to the IMCC. Capability shall be provided to recognize and expedite handling of critical information. The conditioning options available shall include the following:

a) During periods of powered flight, space vehicle checkouts and periodic transmission of bulk data, it shall be possible to convert the data to a coded digital form suitable for transmission to the computing facilities. The conditioned data shall be time tagged and entered into a buffer store and transmitted at a rate not exceeding the capabilities of the communication facilities.

b) During mission periods other than those specified in a), it shall be possible to convert limited telemetry data indicative of critical systems performance to a coded digital form suitable for local display. The conditioned data shall be time tagged and entered into a buffer store. Equipment shall be provided to transmit the stored data or specific critical items to the IMCC.

4.8.6.3 Up-Data Link (Ground-to-Space Data) Subsystem. Certain GCTS sites shall be provided with up-data transmitting facilities. These sites shall be equipped to transmit timing, commands, control data, and other data to the space vehicle and to verify the correctness of certain data through information sent back over the telemetry link. Means shall be provided to check data received for relay transmission to the space vehicle for accuracy and to convert it to the form required for transmission to the space vehicle.

4.8.6.3.1 Near-Earth Sites. The up-data link facilities at near-earth sites shall have the technical characteristics shown in Table 4.8-5.

As a design objective, the coding schemes and the modulation characteristics for the IU and CSM up-data link facilities shall be identical.

4.8.6.3.2 Deep-Space Sites. The up-data link subsystem at deep-space sites shall be integrated with the S-band tracking subsystem specified in Section 4.8.6.1.2.1. Each deep-space site shall have the capability of transmitting data [sequentially] to the CSM and LEM.

The technical characteristics of the up-data link subsystem shall be as given in Table 4.8-6.

4.8.6.4 Space-Ground Voice Communication Subsystem. Certain GCTS sites shall be equipped with a two-way voice communication subsystem to maintain voice communication capability between the Earth and the spacecraft in accordance with the coverage requirements specified in Section 4.8.4.2. This subsystem shall include facilities permitting direct voice communication between the IMCC and the spacecraft.

4.8.6.4.1 Near-Earth Sites. Near-earth sites shall be equipped with VHF radio equipment. The VHF voice subsystem shall have the technical characteristics shown in Table 4.8-5.

4.8.6.4.2 Deep-Space Sites. The voice communication subsystem at deep-space sites shall be integrated with the S-band tracking subsystem specified in Section 4.8.6.1.2.1. Provisions shall be made for selection of the CSM or the LEM channel, or both. Conference capability between the CSM, LEM and IMCC shall be provided.

The receiving and transmitting characteristics of the voice communication subsystem shall be as given in Tables 4.8-4 and 4.8-6 respectively.

4.8.6.5 Television Receiving Subsystem. The capability of receiving television signals from the CSM and LEM shall be provided at all deep-space sites. The television receiving subsystem shall be integrated with the S-band tracking subsystem specified in Section 4.8.6.1.2.1.

The television receiving subsystem shall have the technical characteristics given in Table 4.8-4.

4.8.6.6 Local Site Intra-Communication Subsystem. Suitable voice communications facilities shall be provided at each site to interconnect the various subsystems, operating positions and the inter-site communication network. Local loops and instruments, which may be connected to inter-site communication voice circuits, shall be four-wire throughout. Where necessary, provision shall be made for interconnection with toll telephone channels external to the site.

4.8.6.7 Timing Subsystem. A timing subsystem shall be provided at GCTS sites to act as a source for timing signals necessary to condition and process tracking and telemetry data. The timing subsystem at these sites shall be capable of being synchronized with the United States National Standard of Frequency and Time-Interval (WWV). Synchronization with the National Standard shall be capable of being maintained to within [0.1] milliseconds at each station.

4.8.6.8 Command-Destruct Transmitting Subsystem. Certain near-earth sites shall be capable of transmitting command-destruct data to the launch vehicle during the launch phase.

The technical characteristics of the command-destruct transmitting subsystem shall be the same as those specified in Section 4.7.7 for the launch area command-destruct transmitting subsystem.

4.8.7 Inter-Site Communications Network

The communication network shall interconnect the IMCC, MILA, [HOSC], the GCTS sites, and the RCC.

4.8.7.1 Communication Services. The communication services provided by the inter-site communication network between the IMCC and other stations shall include:

a) equivalent four-wire voice to all stations;

b) high-speed data ([1-3] k bits per second) to and from MILA and selected stations;

c) full duplex teletypewriter data and message facilities (between [30] and [130] bits per sec. and [60] and [100] wpm) to all stations;

d) real time television from MILA;

e) real time television from continental U. S. deep-space station(s) of the quality specified in Section 4.8.6.5. (The network selected must be compatible with this signal.);

f) wide-band data transmission (between ________ and ________ bits per sec) for the transmission to IMCC of spacecraft telemetry composites from MILA during the launch phase, and from the continental U. S. deep-space site(s); and

g) [Communication with the Huntsville Operations Support Center (HOSC)].

4.8.7.2 Communication Network. Land line, microwave and submarine cable facilities shall be used wherever available as primary facilities for the links. Alternate routes shall be provided for all critical circuits and all HF radio links. HF radio links shall be utilized only where other facilities are not available or as back-up links. With the exception of ship receiving installations, space diversity shall be provided on all HF links. Frequency diversity shall be provided on HF links for use during propagation transition periods and for protection against serious interference. Provision shall be made for the communications needed to facilitate handover.

Data terminal equipment that connects to common carrier circuits shall be selected to avoid the need for special delay equalization or other special engineering of such circuits.

All stations shall be linked to the communications center at IMCC.

4.8.7.3 Network Reliability. The following features shall be incorporated in the inter-site communication network:

a) Geographically-diversified circuits shall be provided between IMCC and MILA, between IMCC and overseas gateways, and between IMCC and continental U. S. sites;

b) Redundant high-speed data circuits shall be provided between the communications center at the IMCC and MILA, and for other critical circuits between IMCC and other sites;

c) Standby geographically-diversified alternate circuits shall be provided for all circuits;

d) An indication of the status of each circuit shall be displayed at the IMCC communications center. Teletypewriter and data circuits shall be checked out for circuit continuity, proper operation of the terminal equipment at both ends of the circuit, and the amount of distortion of signals on each link. Signals that do not degrade speech shall be carried continuously on voice circuits to indicate their status; and

e) Selected data circuits shall employ error detection and correction techniques.

4.8.8 Simulation and Training

Selected GCTS sites shall be equipped with technical and operational facilities for conducting simulation and training exercises. These facilities shall allow each of the major subsystems at a site to be exercised individually or in combination with other subsystems at a site on an individual site basis or as part of a network exercise.

Table 4.8-1

Near-Earth Tracking and Acquisition Subsystem Characteristics

Description			Tracking Subsystem			Acquisition Subsystem
			Type I	Type II	Type III	
Operating Frequency Band (Mc)			5400-5900			225-260
Maximum Dynamic Tracking Error	Reference Conditions	Equivalent Range (R) (nm)				
		$\dot{R}$ (ft/sec)				Not Applicable
		$\dot{A}$ (mr/sec)				
		$\dot{E}$ (mr/sec)				
		Range (ft)				Not Applicable
		Range Rate (ft/sec)				Not Applicable
		Azimuth (mr)				
		Elevation (mr)				
Transmitting Subsystem	Modulation Characteristics		Pulse Coding			
	Minimum Effective Radiated Power* (watts)					
Receiving Subsystem	Associated transmitter signal characteristics See Section:		4.5			4.5.2.1; 4.5.3.1; 4.5.4.2.1
	Minimum S/N ratio (db) of :					
	as measured at the:					
	provided by a minimum usable power density (dbw/m^2) of :					
Antenna Beamwidth (deg)						

*Effective Radiated Power — the product of the antenna input power (transmitter output power less transmission line loss) and the antenna power gain at the peak of the main lobe.

Table 4.8-2

Deep-Space Tracking and Acquisition Subsystem Characteristics

Description			Tracking	Acquisition
Operating Frequency Band (Mc)			[2100-2110] Transmit [2280-2290] Receive	[2100-2110] Transmit [2280-2290] Receive
Maximum Dynamic Tracking Error	Reference Conditions	Equivalent Range (R) (nm)	220,000	
		$\dot{R}$ (ft/sec)		Not Applicable
		$\dot{A}$ (mr/sec)		
		$\dot{E}$ (mr/sec)		
	σ	Range (ft)		Not Applicable
		Range Rate (ft/sec)		Not Applicable
		Azimuth (mr)		
		Elevation (mr)		
Transmitting Subsystem	Modulation Characteristics		See Table 4.8-6	
	Minimum Effective Radiated Power (watts)*		See Table 4.8-6	
Receiving Subsystem	Associated transmitter signal characteristics		See Table 4.8-4	
	Minimum S/N ratio (db) of:		See Table 4.8-4	
	as measured at the:		See Table 4.8-4	
	provided by a minimum usable power density (dbw/m^2) of:		See Table 4.8-4	
Antenna Beamwidth (deg)				

*Effective Radiated Power — the product of the antenna input power (transmitter output power less transmission line loss) and the antenna power gain at the peak of the main lobe.

Table 4.8-3

Near-Earth Telemetry Subsystem Characteristics

Description		S-IC	S-II	S-IVB	IU	CSM
Operating Frequency Band (Mc)		225-260	225-260	225-260	225-260	225-260
Receiving Subsystem	Associated transmitter signal characteristics See Section:	4.5.2.1	4.5.2.1	4.5.3.1	4.5.3.1	4.5.4.2.1
	Minimum S/N ratio (db) of:					
	as measured at the:					
	provided by a minimum usable power density (dbw/m^2) of :					
Antenna Subsystem	Beamwidth (deg)					
	Associated receiving subsystems					

Description	CSM Mode I*			CSM Mode II*				CSM Mode III* (Ranging)	
Operating Frequency Band (Mc)	[2285-2290]			[2285-2290]				[2285-2290]	
Associated transmitter signal characteristics	Voice FM/PM	Telemetry PCM/PM/PM	Carrier	Voice FM/PM	Telemetry PCM/PM/PM	Ranging Code PM	Carrier	Ranging Code PM	Carrier
See Section:	4.5.4.1.3	4.5.4.2.2	4.5.4.6.1.2	4.5.4.1.3	4.5.4.2.2	4.5.4.6.1.2	4.5.4.6.1.2	4.5.4.6.1.2	4.5.4.6.1.2
Minimum S/N ratio (db) of:									
as measured at the:									
provided by a minimum usable power density (dbw/m^2) of:									

*CSM operating modes shall be as defined in Section 4.5.

FOLDOUT FRAME

[redacted]

Table 4.8-4

Deep-Space S-band Receiving Subsystem Characteristics

CSM Mode IV*			CSM Mode V*				CSM Mode VI* (Tape Playback)			CSM Mo (Emergen
[2285-2290]			[2285-2290]				[2285-2290]			[2285-2
Voice FM/PM 4.5.4.1.3	Telemetry PCM/PM/PM 4.5.4.2.2	Carrier 4.5.4.6.1.2	Voice FM/PM 4.5.4.1.3	Telemetry PCM/PM/PM 4.5.4.2.2	Ranging Code PM 4.5.4.6.1.2	Carrier 4.5.4.6.1.2	Voice FM/FM 4.5.4.1.3	Telemetry PCM/PM/FM 4.5.4.2.2	Analog Tape Playback FM/FM 4.5.4.1 4.5.4.2	Voi FM 4.5.4.1.3

FOLDOUT FRAME 2

[redacted]

de VII* cy Voice)	CSM Mode VIII* (Keyed Operation)		CSM Mode IX* (Television)	Lunar Excursion Module				
290]	[2285-2290]		[2280-2290]	[2280-2285]				[2280-2290]
ce M	Key	Carrier	Television	Voice	Telemetry	Ranging	Carrier	Television
	4.5.4.1.3	4.5.4.6.1.2	4.5.4.9	4.5.5.1.1	4.5.5.2	4.5.5.7.1	4.5.5.7.1	4.5.5.6

FOLDOUT FRAME 3

Table 4.8-4

Deep-Space S-band Receiving Subsystem Characteristics

[redacted]

Table 4.8-5

Near-Earth Up-Data Link and Voice Subsystem Characteristics

Description		Up-Data	Voice
Operating Frequency Band (Mc)		400 - 450	[250-300]
Transmitting Subsystem	Modulation Characteristics	[Transmission rate-1000bps]	DSBAM
	Minimum Effective Radiated Power* (watts)		
Receiving Subsystem	Associated transmitter signal characteristics	Not Applicable	See Section 4.5.4.1.1
	Minimum S/N ratio (db) of:	Not Applicable	
	as measured at the:	Not Applicable	
	provided by a minimum usable power density (dbw/m^2) of:	Not Applicable	
Antenna Subsystem	Beamwidth (deg)		
	Associated transmitting and receiving subsystems		

*Effective Radiated Power — the product of the antenna input power (transmitter output power less transmission line loss) and the antenna power gain at the peak of the main lobe.

[redacted]

[redacted]

Table 4.8-6

Deep-Space S-Band Transmitting Subsystem Characteristics

Description	Command and Service Module			Lunar Excursion Module		
Operating Frequency Band (Mc)	[2105 - 2110]			[2100 - 2105]		
Modulation Characteristics	Voice FM/PM	Up-Data PSK/FM/PM	Ranging Code PM	Voice	Up-Data	Ranging Code
Baseband Characteristics	[2.3] Kc	[1 kbps NRZ data on 2Kc tone with m = 3.14 and 1Kc tone]	[500 Kc PR code]			
Subcarrier	[30] Kc	[70] Kc	[500 Kc clock in-phase]			
Modulation Index (baseband on subcarrier)			[1.57]			
Modulation Index (subcarrier alone on carrier)						
Minimum Effective Radiated Power* (watts)						

*Effective Radiated Power — the product of the antenna input power (transmitter output power less transmission line loss) and the antenna power gain at the peak of the main lobe.

[redacted]

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4.9 Integrated Mission Control Center.

Primary command and decision-making responsibility rests with the Integrated Mission Control Center on earth. Each mission will be conducted in accordance with a detailed mission plan which includes specific actions to be taken in case of recognized emergencies and guidelines established for actions to be taken in unforeseen contingencies. Responsibility for the execution of this detailed mission plan will normally be delegated to the on-board Crew Commander. Deviations from the plan require approval from the IMCC. For emergencies requiring immediate action, or during periods of no communications with the IMCC, the responsibility for command shall reside with the on-board Crew Commander.

4.9.1 Scope.

The IMCC shall be equipped to:

a) Direct overall mission conduct.

b) Generate guidance parameters and monitor guidance computations and propulsion capability.

c) Evaluate the performance and capabilities of the space vehicle equipment systems.

d) Evaluate the capabilities and status of the spacecraft crew and life support systems.

e) Evaluate, direct and supervise activities of the ground support systems.

f) Authorize and monitor launch operations.

g) Direct the recovery activities.

h) Conduct simulation and training exercises.

i) Schedule and regulate transmission of recorded data from sites.

j) Support post-mission analyses.

k) Record pertinent data.

l) Maintain a satisfactory level of performance.

m) Initiate and control the checkout of the ground network.

The IMCC shall provide a Mission Operations Control Room (MOCR), with Support Areas and Support Systems to serve as the command center for the operational Apollo mission.

4.9.2 Facility Requirements.

4.9.2.1 Mission Operations Control Room.

4.9.2.1.1 General.

The MOCR shall contain a group of specialized functional locations (called stations) where specific information will be available that contributes directly to the decisions by the Operations Directorate as to whether to continue the mission as planned, modify the mission, or order an abort.

The functional stations within the MOCR shall include:

a) Operations Directorate.

b) Flight Dynamics.

c) Spacecraft and Launch Vehicle Systems.

d) Spacecraft Crew and Environment.

e) Ground Complex Control.

f) Recovery Operations Direction.

4.9.2.1.2 Operations Directorate Station.

4.9.2.1.2.1 Function. The Operations Directorate shall direct overall mission conduct from pre-launch through recovery.

4.9.2.1.3 Flight Dynamics Station.

4.9.2.1.3.1 Function. This station shall be equipped to:

a) Monitor present trajectory and trajectory changes.

b) Monitor guidance computations.

c) Monitor propulsion capability remaining.

d) Effect ground-controlled trajectory changes.

4.9.2.1.4 Spacecraft and Launch Vehicle Systems Station.

4.9.2.1.4.1 Function. This station shall be equipped to assess the performance and capabilities of the space and launch vehicles equipment systems including diagnostic assistance and fault isolation.

4.9.2.1.5 Spacecraft Crew and Environment Station.

4.9.2.1.5.1 Function. This station shall be equipped to monitor and evaluate the capabilities and state of the spacecraft crew and life support systems.

4.9.2.1.6 Ground Complex Control Station.

4.9.2.1.6.1 Function. This station shall be equipped to evaluate, direct and supervise the activities of the ground support system including network stations, communication links, internal communications and support systems.

4.9.2.1.7 Recovery Operations Direction Station.

4.9.2.1.7.1 Function. This station shall be equipped to direct the activities of the Recovery Forces and inform the Operations Directorate of their status and performance.

4.9.2.2 Support Areas.

4.9.2.2.1 General. Support Areas shall be provided in the vicinity of the MOCR for use by the Operations Control Support Staff. These shall house the necessary display, communications, control, and recording equipments to support staff members in the performance of their assigned activities. The areas shall be divided according to function and shall include the following:

a) Crew Performance and Life Support Analysis Area.

b) Space Vehicle Performance Analysis Area.

c) Trajectory Monitoring and Analysis Area.

d) Network Support Staff Area.

e) Operations and Procedures Support Staff Area.

f) Meteorology and Space Environment Support Area.

g) Training and Simulation Area.

h) Public Relations Area.

4.9.2.2.2 Crew Performance and Life Support Analysis Area. This group shall be equipped to monitor and predict crew and life support systems performance and report all abnormal conditions to the MOCR. This group shall be connected to the MOCR by both voice and video links.

4.9.2.2.3 Space Vehicle Systems Performance Analysis Area. This group shall be equipped to monitor and predict vehicle system performance and inform the MOCR of any malfunction or predicted deficiency. They shall be connected to the MOCR by both voice and video links.

4.9.2.2.4 Trajectory Monitoring and Analysis Area. This group shall be equipped to monitor and analyze all trajectory and trajectory change data to provide direct support to the Flight Dynamics Station. They shall be connected to the MOCR by both voice and video links.

4.9.2.2.5 Network Support Staff Area. A network support staff area shall be provided to accommodate the display, communication, and control equipment needed for operational monitoring and control of system communications network, This area shall be equipped to monitor the status and determine the capability of all sites. Status displays of all sites and communication links shall be provided. This area shall have direct communications with all sites and the MOCR.

4.9.2.2.6 Operations and Procedures Support Staff Area. This group shall be equipped to maintain the mission rules and incorporate changes or modifications to the standard operating procedures as required. This group shall be equipped to assist the Operations Directorate in all procedural matters.

4.9.2.2.7 Meteorological and Space Environmental Area. The meteorological and space environment area shall collect and maintain global weather forecasts and conditions. The area shall predict solar flares and other environmental phenomena and predict their effects on r-f propagation and spacecraft crew safety

4.9.2.2.8 Training and Simulation Area. This area shall be equipped to monitor, direct and control simulation and training exercises to ensure mission readiness for all elements of the Apollo systems.

4.9.2.2.9 Public Relations Area. The public relations area shall maintain liaison with the news media by controlling and directing the release of general mission information.

4.9.2.3 Support Systems.

4.9.2.3.1 General. Technical support for the MOCR shall be provided by specialized support systems. In general, equipment for these systems will be located throughout IMCC rather than in specific areas.

4.9.2.3.2 Display Systems. Displays shall provide a primary interface between personnel and equipment systems within the IMCC. The display systems shall maximize the ability of the decision-making personnel to direct and control all activities related to the operational support of Apollo missions. This system shall consist of group displays, individual displays, and distribution equipment. The displays shall be flexible to accommodate different quantities for different mission phases and provide for future growth.

Group displays shall provide a common orientation and display general information on mission status and progress.

Individual displays shall provide detailed information related to specific tasks. In general the detailed information will be displayed in the support areas with a display call up facility available at stations in the MOCR. Individual displays shall have controls to enable operators to request information. Individual displays shall be similar where possible and special purpose displays utilized only in cases where individual displays cannot perform the required display functions.

4.9.2.3.3 Communications System. The communications system shall contain the equipment to channel all incoming and outgoing communications traffic, to switch and route all internal communications traffic and the equipment for IMCC inter-communications. This system shall be equipped to determine the quality of communications with the sites and to maintain adequate communication capabilities during the mission. A message center for teletypewriter messages, and a display of the status of the local connecting equipment and links shall be provided. Facilities to transform live and recorded television signals to a format suitable for use by commercial television facilities shall be provided.

The communication system shall have a minimum capacity for terminating ____ teletypewriter circuits, ____ low speed data circuits, ____ high speed data circuits, ____ wide band data circuits, ____ voice circuits and television circuits. Switching equipment shall automatically route, store and sequence specified incoming and outgoing transmissions. An intercept position shall be provided to receive automatically messages rejected by the switching equipment, together with a transmit position for retransmission of intercepted messages after suitable correction.

The IMCC intercommunications shall include closed circuit TV, four-wire voice communications including conference loops and a public address system. Flexibility shall be provided to enable the communications systems to be adapted to the needs of a particular Apollo mission.

4.9.2.3.4 Computation System. The computation system shall be equipped to receive, store and reduce data, make calculations and predictions, and provide data in response to control actions and for displays. The computation equipment shall be capable of supporting the simulation system.

The real time computer complex shall be capable of handling real time peak loads of:

inputs	
tracking data	____ K bits/sec
space vehicle telemetry including checkout	____ K bits/sec
launch control telemetry	____ K bits/sec
ground network status	____ bits/sec
recovery status	____ bits/sec
outputs	
display information	____ K bits/sec
operations direction	____ K bits/sec
abort contingencies	____ K bits/sec
network control	____ bits/sec
acquisition data	____ bit/sec

The computation equipment shall have the capability to compute flight paths, maneuvers and corrections from both earth-based and spacecraft data independently and in combination.

The computation equipment shall provide in-flight checkout assistance to the space vehicle to facilitate systems evaluation and rapid fault isolation as described in section 4.6.

Parallel computer operation shall be used during all critical mission operations.

4.9.2.3.5 <u>Simulation, Checkout and Training System (SCATS)</u>. This system shall contain equipment to simulate telemetry, trajectory, and command data as well as voice communications, for subsystem tests, open loop simulations, closed loop simulations and ground network checkout.

Simulations shall exercise all Apollo elements in one combination or another to optimize system performance for actual mission operations. The SCATS equipment shall be capable of changing or perturbing system inputs and outputs to simulate all conditions during any phase of a mission.

The subsystem tests shall provide fixed programmed inputs to exercise particular subsystems including site test programs to test network data flow, input/output programs to test main computing facilities, etc. Open loop simulations shall provide a fixed mission profile to enable the Operations Directorate and staff to become thoroughly familiar with the procedures to be used during the nominal mission. Closed loop simulations shall provide a variable mission profile to enable the Operations Directorate and staff to exercise their decision-making functions.

If possible the design of simulation procedures shall not affect the sizing of the communications and computational facilities otherwise required for the operational mission. The capability shall be provided to coordinate simulation facilities located at IMCC with those at LCC, RCC and the remote sites. The design of the IMCC facilities shall provide positive isolation of mission and simulation traffic.

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4.10 Recovery.

4.10.1 General. Recovery is defined as the location and retrieval of the astronauts, scientific samples and data, and spacecraft at the termination of the mission. Recovery support provided for lunar landing missions shall include coverage for all abort situations. The primary objectives of recovery shall be:

4.10.1.1 To locate, assist, and retrieve the astronauts from land and water impacts with primary emphasis on their safety.

4.10.1.2 Preservation and retrieval of scientific samples and data.

4.10.1.3 Preservation and retrieval of the spacecraft.

4.10.1.4 Completion of operations within the specified time intervals.

4.10.2 Landing Areas.

4.10.2.1 Planned Landing Areas. Planned Landing Areas are those programmed for use at the termination of normal flights and at flight termination under controlled abort situations. The following are Planned Landing Areas:

4.10.2.1.1 Nominal Landing Area(s). A region(s) surrounding the point(s) selected for termination of a successful mission will constitute the Nominal Landing Area(s).

4.10.2.1.2 Abort Landing Areas.

4.10.2.1.2.1 Launch Site. Abort prior to, or immediately after, first stage ignition will return the spacecraft to land or offshore in the vicinity of the launch pad. Special retrieval problems are imposed by the terrain and shallow water in the vicinity of Cape Canaveral.

4.10.2.1.2.2 Pre-Orbit. Aborts which occur during powered flight before injection into earth orbit and which place the spacecraft outside the Launch Site Landing Area will terminate in the Pre-Orbit Landing Area.

4.10.2.1.2.3 Earth Orbit. Orderly curtailment of the mission during the earth-orbital phase will place the spacecraft at one of the pre-programmed Earth Orbit Landing Areas.

4.10.2.1.2.4 Lunar Transfer. Lunar Transfer Landing Areas are those selected for pre-programmed abort trajectories which may be originated during flight to the moon.

4.10.2.2 Contingency Landing Areas. All landings in areas other than Planned Landing Areas are considered Contingency Landings. Certain areas which are preferable from viewpoints of surface environment and availability of assistance will be designated as Preferred Contingency Landing Areas.

4.10.3 Recovery Forces.

4.10.3.1 Recovery from Planned Landing Areas. Recovery forces deployed at the Planned Landing Areas shall be equipped to locate the spacecraft, to establish voice communications with the astronauts, to render immediate assistance for their health and safety, to protect the spacecraft and scientific samples from loss or damage, to communicate with the IMCC, and to retrieve and transport the astronauts and spacecraft.

4.10.3.2 Recovery from Contingency Landing Areas. Assistance forces shall be suitably deployed and equipped to proceed to Contingency Landing Areas to locate the spacecraft, to establish voice communications with the astronauts, to render immediate assistance for their health and safety, and to take all possible measures to protect the spacecraft and scientific samples from loss or damage. Retrieval shall be pre-planned for Preferred Contingency Landing Areas. At other Contingency Landing Areas, retrieval forces and equipment shall be dispatched from the nearest point at which suitable facilities are available as soon as the location of the landing area can be predicted.

4.10.4 Time Intervals. The recovery forces shall be deployed and equipped to perform recovery operations at the point of impact within the time intervals tabulated below.

Landing Area	Render Initial Assistance	Initiate Retrieval	
		Astronauts	Spacecraft
Nominal			
Launch Site			
Pre-Orbit			
Earth Orbit			
Lunar Transfer			
Preferred Contingency			
Other Contingency			*

*Time interval cannot be pre-determined.

4.10.5 Recovery Facilities.

4.10.5.1 Communications.

4.10.5.1.1 Recovery forces shall be equipped to maintain communications with the IMCC to provide recovery status information (impact area weather, predicted recovery intervals, suggested impact area adjustments, etc.) and to receive mission status information (predicted impact location, condition of astronauts, spacecraft, recovery aids, etc.) throughout the mission.

4.10.5.1.2 Recovery forces shall be equipped to maintain voice communications with the astronauts throughout recovery operations and to utilize the diversity of frequencies and operating modes specified for spacecraft recovery communications in Section 4.5.4.

4.10.5.2 Location, Assistance and Retrieval Equipment.

4.10.5.2.1 Recovery forces shall be equipped to locate the spacecraft, to operate compatibly with the spacecraft-borne recovery and survival aids and to retrieve the astronauts, the scientific samples and data, and the spacecraft from land or water areas.

APPENDIX A-1

Acronyms and Abbreviations

AMR - Atlantic Missile Range.

CEP - Circular Error Probable - radius of a circle that encompasses 50% of the probable points of impact on the surface of interest.

CM - Command Module.

dbw - Power level in decibels referred to one watt.

DDAS - Digital Data Acquisition System.

F-1 Engine - A liquid propellant rocket engine, designed to develop a nominal thrust 1.5 million pounds at sea level. The F-1 uses LOX and RP-1 as a propellants.

GCTS - Ground Communications and Tracking System.

HF - High Frequency (3 to 30 megacycles).

IMCC - Integrated Mission Control Center.

IMU - Inertial Measurement Unit.

IU - Instrument Unit, a portion of the Saturn V Launch Vehicle.

J-2 Engine - A liquid propellant rocket engine, designed to develop a nominal vacuum thrust of 200,000 pounds. The J-2 uses LOX and liquid hydrogen as propellants.

LCC - Launch Control Center.

LEM - Lunar Excursion Module.

LES - Launch Escape System.

LOC - Launch Operations Center.

LOR - Lunar Orbit Rendezvous.

LOX - Liquid Oxygen.

MD(S) - Deputy Director (Systems) - OMSF

MD(P) - Deputy Director (Programs) - OMSF

MILA - Merritt Island Launch Area.

MOCR - Mission Operations Control Room at IMCC.

mr - milliradians.

mm - millimeters.

nm - nautical miles.

OMSF - Office of Manned Space Flight.

q - Dynamic pressure.

RCC - Recovery Control Center.

RP-1 - A kerosene-base fuel for rocket engines.

RTCC - real time computer complex

S-Band - For the purposes of this specification, S-Band is defined as frequencies ranging from 2110 MC to 2300 MC.

S-IC - A launch vehicle delivering a nominal thrust of 7-1/2 million pounds at sea level, obtained from 5 F-1 rocket engines. First stage of Saturn V launch vehicle.

S-II - A launch vehicle delivering a nominal vacuum thrust of 1 million pounds, obtained from 5 J-2 rocket engines. Second stage of Saturn V launch vehicle.

S-IVB - A launch vehicle delivering a nominal vacuum thrust of 200,000 pounds, obtained from 1 J-2 rocket engine. Third stage of Saturn V launch vehicle.

SCATS	- Simulation, Checkout and Training System
SM	- Service Module.
UHF	- Ultra High Frequency (300 to 3000 megacycles).
VHF	- Very High Frequency (30 to 300 megacycles).
α	- Angle of attack.
σ	- Standard Deviation

APPENDIX A-2

Summary of Design Objectives*

1.5 Certain requirements in this specification have been identified as design objectives to reflect a degree of uncertainty on the practicability (in terms of mission reliability, scheduling, cost, etc.) of the requirement. Such design objectives must be pursued by the initiation and conduct of studies which are to be accomplished in sufficient time to allow incorporation of the feature(s) in the system design, if proven practicable. If study results should show a design objective requirement to be impracticable, the requirement will be appropriately modified or deleted.

4.1 Apollo Space Vehicle.

4.1.3.1 As a design objective, the space vehicle shall be designed so that there is a 99.9% probability of not having meteoroid penetration result in having to abort the mission during exposure to the meteoroid environment specified in OMSF Program Directive M-DE 8020.008.

4.2 Launch Vehicle.

4.2.1.2 As design objectives, the launch vehicle shall be capable of achieving the required lunar transfer trajectory using the following conditions:

a) Orbital start of the S-IVB with the first two stages carrying an off-loaded S-IVB with its payload to earth orbit.

b) One engine out in the S-IC ____ seconds after lift off (for flight control purposes only).

c) One engine out in the S-II from the time of ignition.

4.2.1.3 As a design objective, the Saturn V launch vehicle shall be capable of boosting the following net payloads at injection into the [72 hour] lunar

*Section numbers shown indicate where design objectives appear in body of specification.

transfer trajectory. Net payload consists of all weight at the time of injection forward of the Instrument Unit. The payloads are based on launching from the Merritt Island Launch Area with a thrust-to-weight ratio at lift-off of 1.25, an azimuth of 90°±18°, jettisoning the 6600 pound LES 10 seconds after ignition of the second stage, parking 4 1/2 hours in earth orbit, operating 2 hours after injection before separation of the S-IVB, and providing an orbital injection window time of____minutes.

c) 97,500 pounds for the normal operational mode.

d) 90,000 pounds for the design objectives of either orbital start of the S-IVB or engine out operation of the S-II stage from the time of ignition.

4.2.3.1.1 As a design objective, the S-IC stage shall be capable of utilizing a one-engine-out condition after the time maximum q.

4.2.3.2.1 As a design objective, the S-II stage shall be capable of utilizing a one-engine-out condition.

4.2.3.3.4 As a design objective, a third burn of the S-IVB shall be used after separation from the spacecraft to obtain escape velocity to prevent re-entry into the Earth's atmosphere. If this design objective is achieved, the requirement of 4.2.3.3.3 may be modified.

4.3 Spacecraft.

4.3.1 As a design objective, the Apollo spacecraft shall be capable of being off-loaded to 82,500 pounds at injection and provide a margin of 10 percent over the minimum velocity increments indicated in Appendix A-3.

4.3.2 As a design objective, propellant temperature in the spacecraft shall be maintained within the proper range without the use of active temperature control systems. Active temperature control systems as used here include all temperature control systems with moving parts, or systems that require controlled orientation with respect to the Sun.

4.3.2.1.6 As a design objective, the CM structure shall be capable of withstanding the thrust loads encountered in using the LEM for spacecraft abort propulsion.

4.3.2.3 As a design objective, the LEM structure shall be capable of transmitting the thrust loads encountered in using the LEM for spacecraft abort propulsion.

4.3.3.2.1 As a design objective, propellants in the main engine tanks of the SM shall be transferable to the SM reaction control system.

4.3.4 As a design objective, systems shall also be provided for tracking the LEM from the CM.

4.3.8 As a design objective, the Command Module parachute system shall be controllable for selecting the landing point on Earth.

4.3.9.1.3 (d) As a design objective, the spacesuit shall permit the reading of displays and operation of controls with no impairment over "shirtsleeve" operation.

4.3.9.1.4 As a design objective, one spare back pack shall be provided for LEM crew.

As a design objective, it shall be possible for a crewman to recharge his back pack without assistance while standing on the lunar surface.

4.3.9.2.1.2 As a design objective, equipment shall be provided in the CM and LEM for automatic gas analysis.

4.3.9.2.2 As a design objective, thermal control of external heat fluxes to the interiors of the CM/SM and LEM shall be passive and a function of the structural design and surface finish of the spacecraft.

4.3.10.2 (c) As a design objective, displays and controls in the CM & LEM shall be designed so that no significant lowering of the probability of crew safety shall occur when crew functions are performed by crewmen wearing inflated pressure suits.

4.4.3 Navigation, Guidance and Control Design Requirements.

4.4.3.2 (Also appears in section 4.4.1) As a design objective, the CM system will have the capability of guiding the space vehicle from earth parking orbit to completion of injection into a lunar transfer trajectory.

4.4.3.13 As a design objective, the design of the CM guidance and control system shall be such that, in case it is necessary to abandon the mission, the CM can be returned safely to Earth by ground-based radio command by request of the crew if they are functioning or without active crew participation if they are incapacitated.

4.4.3.14 The LEM shall have the capability, independent of lunar-based landing aids, of landing at a pre-selected point on the lunar surface with a design objective circular error probable (CEP) of one-half mile without necessitating expenditure of the hover time provided for landing site selection.

4.4.3.15 The LEM shall house additional capability of landing at a pre-selected landing point through the use of a lunar-based beacon or equivalent, with a design objective CEP of 100 feet.

4.4.3.16 (Also appears in section 4.4.2.4) As a design objective, the LEM shall be capable of performing a descent from lunar orbit and of soft-landing at a pre-selected landing point on the lunar surface without the participation of the LEM crew except, if necessary, for initial alignment of the LEM Inertial Measurement Unit prior to separation from the CM.

4.4.3.19 (Also appears in section 4.4.2.4) As a design objective, the mechanization of the CM and the LEM shall be such that the CM can signal the time of launch to the LEM and subsequently range and track the LEM for the purpose of relative CM-LEM position determination and as an aid to rendezvous.

4.4.3.20 (Also appears in section 4.4.2.4) As a design objective, the CM and and LEM mechanization shall be such that it is possible for the CM to radio guide the LEM, by voice and/or automatic radio command, into lunar orbit.

4.5 Space Vehicle Communications.

4.5.4.3 Ground-to-Space Data Subsystem. As a design objective, verification of selected received data shall be accomplished by repeating the data received at the CM over the telemetry system for comparison on the Earth.

4.5.4.4 (a) LEM-to-CM Data Subsystem. As a design objective, the LEM-to-CM data subsystem shall provide reception at the CM of data from the LEM.

4.5.4.5 (a) CM-to-LEM Data Subsystem. As a design objective, the CM-to-LEM data subsystem shall provide data transmission service from the CM to the LEM.

4.5.4.7 (a) CM Tracking Subsystem. As a design objective the CM/SM shall be equipped to range and track the LEM.

4.5.5.1.3 (a) LEM-Back Pack Voice Subsystem. As a design objective, conference capability between a lunar explorer, LEM, and the Earth shall be provided.

4.5.5.4 (a) LEM-to-CM Data Subsystem. As a design objective, the LEM-to-CM data subsystem shall be capable of providing data transmission service from the LEM to the CM.

4.5.5.5 (a) CM-to-LEM Data Subsystem. As a design objective, the CM-to-LEM data subsystem shall be capable of providing reception at the LEM of data from the CM.

4.5.5.6 (a) Space-to-Ground Television Subsystem. The LEM shall incorporate the capability of taking and transmitting TV pictures directly to the Earth during lunar operations and, as a design objective, during ascent and descent.

4.6 Checkout.

4.6.3.3 (second paragraph) As a design objective, the capability shall be provided to perform checkout of the space vehicle (consisting of the CM, SM, LEM, S-IVB and IU) during first Earth parking orbit.

APPENDIX A-3

Velocity Increment Budget

(To be included in a later edition)